THE

STUDENT'S

PRACTICAL CHEMISTRY.

A TEXT-BOOK ON

CHEMICAL PHYSICS AND INORGANIC AND
ORGANIC CHEMISTRY.

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Part II.

CHEMISTRY—GENERAL DEFINITIONS.

INORGANIC CHEMISTRY.

NOTES ON CHEMISTRY.

PART I.

CHEMICAL PHYSICS.

In CONSEQUENCE of the close relation existing between various physical forces, and the sciences which discuss them, it is necessary in treating one subject, to use some terms belonging strictly to other affiliated departments. Thus in our present abstract of Chemistry, many terms of Mechanics, Electricity, Heat, Light, etc., must be occasionally employed, and we therefore place in this Introduction, such definitions and brief explanations, as may render such terms, when afterwards employed, sufficiently intelligible.

GENERAL PROPERTIES OF MATTER.

Impenetrability.—The power of occupying space exclusively, or so that another portion of matter cannot at the same time exist in the same place.

Extension, Bulk or Volume.—The amount of space occupied by any substance, expressed in some unit, arbitrarily established. See APPENDIX, page 283.

Figure.— The outline or boundary of any body, or portion of matter. This is generally expressed by certain Geometrical terms, such as Sphere, Cube, Pyramid, Prism, Octohedron, etc.

Matter is Indestructible.—By this term, we express the fact, that no force exists in nature, capable of annihilating an atom of matter; and that, amid all the changes going on in bodies, by the operation of natural causes and the artificial conditions of our experiments, no particle perishes or ceases to exist, but that which was once in existence, may always be found, however changed in its form, by a sufficiently thorough search.

Example. — Gun-cotton ignited, explodes and disappears, being converted into gas; but if the explosion is conducted in an exhausted glass flask, while the cotton disappears, the whole apparatus will weigh as much as before the explosion: proving that no loss of matter has occurred.

MECHANICAL FORCES.

Gravitation.

Gravitation is the force of attraction which exists between every atom in the universe and every other atom, drawing bodies together with a force, which varies, directly with the products of their masses, and inversely with the squares of their distances.

Gravity.—This term is used to express that part of the universal gravitation, which exists between the earth and bodies near its surface.

Weight is the numerical expression of the Gravity of any body (i. e. the attraction between it and the Earth) reduced to some arbitrary unit, as the pound, ton, ounce, grain, etc. See APPENDIX, page 287.

Mass.—By this word we indicate the quantity of matter in a body. This is always expressed, relatively, by the

weight. Thus we believe that a body weighing 2 lbs., has twice as much matter in it as a body weighing 1 lb.

Specific Gravity, or Density.—By this we indicate the relative weight of equal volumes or bulks, of different substances. Thus, as a cubic inch of iron weighs 7 times as much as a cubic inch of water, we say that their densities are as 7 to 1.

In practice the density of water at a temperature of 60°, is assumed as the unit of density for all solids and liquids, and air at 60° with the barometer at 30 ins. is the unit for gases. When, therefore, we say that the density of iron is 7, of mercury 13½, of gold 19, of alcohol .792, of chlorine 2.5, and of hydrogen .069, we mean that the first four of these bodies are respectively 7,13½, 19 and .792 times as heavy as equal bulks of water; and that the two last are respectively 2.5 and .069, or 1-14th as heavy as equal bulks of air.

Fig. 1.

The methods for determining these densities, it would be out of place to explain here in full. But we may remark briefly, that THE DENSITY OF SOLIDS is determined, by finding their loss of weight when immersed in water, as is shown in the figure, and then dividing the whole weight by this loss, which gives the density. Thus, 56 grains of iron will lose in water 8 grains, then $56 \div 8 = 7$ which is the density of iron.

The Density of Liquids is found directly by providing a vessel which will hold a known weight (say 1000 grains) of water, filling this with the liquid to be examined, and weighing. Thus, a 1000 gr. bottle (see figure) being filled with mercury, weighs 13,500 grs. the density of mercury is therefore 13½; the same bottle filled with alcohol would have weighed 792 grs., its density therefore is .792.

Fig. 2.

Fig. 3.

Fig. 4.

The density of liquids is also in practice frequently determined by the HYDROMETER. Here the liquid to be tested is poured into a tall jar (see figure 3) and a little tube with a divided scale, etc. (see figure 4) is floated in it. The lighter the liquid the lower the tube will sink, before it displaces enough fluid to support its weight, and thus by observing the degree on the stem to which it sinks, and, referring to a table carefully prepared, which always accompanies the instrument, the density of the liquid may at once be read off.
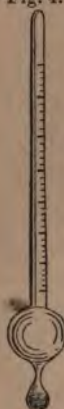
Hydrometers are sometimes used as a rough means of determining the amount of some salt, etc. in a solution, by its effect on the density. In these cases, the tables are often prepared to indicate this fact, and make no reference to the density. This, for example, is the case in the Lactometer, the Vinometer, the Saccharometer, etc.

The Density of Gases is determined likewise by weighing them in a closed vessel of known capacity, with very careful attention to the temperature and height of the barometer.

Cohesion.

Cohesion is that force of attraction which exists between adjacent particles of matter. E. g. The force which holds together the particles of gold, in a sheet of gold leaf, or of lead in a bullet, and which will cause various

parts of gold leaf firmly pressed together, or two halves of a bullet lately cut, to cling with notable tenacity; as may be seen by the experiment figured in the drawing, where two plates of lead, cleaned and pressed together, will support a large weight, by their cohesion.

Fig. 5.

This force varies greatly with different materials, as may be seen by their various strength, tenacity, or resistance to rupture. See APPENDIX, page 290.

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Adhesion is a term applied to this force, for convenience, when it acts between *different* substances. E. g. Solder and Gold, Silver, etc.; Wood and Glue, and the like. This is, however, a name for a *class of actions*, not for a new or different force.

Capillary Attraction again is the name given to that class of cohesive actions, where this force is exerted between a solid of a tubular, lamillar, or porous structure, and a liquid, and causes a change of level in the liquid, where it comes within reach of the attraction of the solid. Ex. The rising of oil in a lamp-wick, of sap in trees, of water in the earth, etc.

Fig. 6.

The height varies with the diameter of the tube and the liquid used, as may readily be shown by the apparatus, Fig. 6.

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Diffusion of Liquids or Gases is the action by which liquids or gases of different densities will mix with or dissolve in each other, even against gravity. It seems a direct result of "capillary cohesion," the porous nature of liquids and gases being taken into account. E. g Fill a glass half full of oil of vitriol, sugar syrup or the like heavy liquid; pour upon it gently a layer of water; after a time they will become completely mixed. So if the vessels $a\ e$ connected by a fine tube are filled, (a with light hydrogen, e with heavy carbonic acid), they will soon be found to have completely mingled their contents.

Fig. 7.

Osmose, indicates a similar interchange in liquids, when it takes place through a porous membrane, as moist bladder, parchment paper, etc. In this case the rate of transfer varies greatly in different substances, and thus may be made a means of analysis. This subject has been extensively studied by Graham, and under the title "DIALYSIS," is fully discussed in several papers. See Franklin Institute, Journal, Vol. 44, pp. 181 and 253.

Fig. 8.
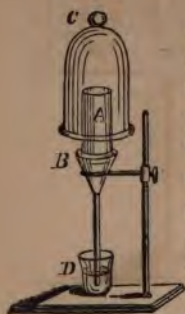
Transpiration of Gases indicates the same action in the case of æriform bodies, a most striking example of which is furnished by the following experiment. The porous cup or battery cell A, is cemented, bottom upward with plaster of Paris, in the long glass funnel B. The bell jar C filled with hydrogen being then placed over A, this gas will transpire into the interior of A and B, so rapidly as to force out the air in a series of bubbles, through

water placed in the little vessel D, into which dips the end
of B. The bell jar being then removed, the hydrogen
which has passed into A, will transpire again into the
outer air, with such energy, as to raise the water from D,
to a great height in the funnel tube.

The wonderful power which some porous bodies, such
as charcoal, coke, platinum black, etc., possess, of con-
densing gases, seems closely allied to the above actions,
and to result like them from cohesive attraction.

Repulsion.

Repulsion is that force of mutual recession, which exists
between adjacent particles of matter, opposing cohesion,
and greatly affecting its action in many cases. This force
is most largely exhibited in gases, and gives to these bodies

Fig. 9.

their almost unlimited powers of expansion. Thus, if a
flask, containing a bubble of air, but otherwise filled with
water and inverted in a vessel of the same, is placed under

the receiver of an air-pump, as the atmospheric pressure is removed, the bubble will expand, until it fills the whole flask. It is this force of "repulsion" which gives to all matter its elasticity of volume. It is closely related to heat, being, perhaps, another consequence of the same cause, i. e. the motion of all material atoms. See page 17.

Polarity.

Polarity is that directive force which causes adjacent particles of matter to assume definite relative positions. Its fullest exhibition is found in the phenomena of crystallization, but it is the origin of all rigidity of form to be found in solid bodies.

The subject of Crystallography is too extensive to be here discussed, and we must confine ourselves to a few references and general statements.

By reason of polarity, the particles of solids (and those of liquids and gases, when about to assume the solid form) strive to arrange themselves in definite directions as regards each other, thus forming lines, parallel or inclined; plates, and solids of geometric forms, as cubes, prisms, octohedrons, and the like.

Examples of this action are furnished in the snow crystals, frost markings on window-panes, and the action of a slowly evaporating solution of common salt, etc.

In many cases this polarity opposes cohesion, and thus produces a strain in the crystallized body, which gives it a power of affecting light in a remarkable way. See page 69.

HEAT.

Heat is the name by which we indicate the cause of a sensation experienced when we approach a fire ; and of certain effects, expansion, fusion, etc., commonly observed to be connected with the same. This cause, we have now every reason to believe, is simply a motion, greater or less, among the particles of bodies. In other words, the par-

ticles of a hot body are moving more rapidly than those
of a cold one, and from this more rapid motion, come all
the properties by which hot substances are distinguished
from cold ones. These rapid vibrations, communicated by
contact to the hand, affect the nerves of touch with the
"tingling" sensation called "heat." When this motion of
particles becomes more rapid, it causes them to pass
through greater distances, to push each other apart, and
to strike with greater force against the sides of a contain-
ing vessel; hence arise the phenomena of expansion.

This rapid motion in solid particles, increasing, may at
last throw them beyond the range of the polar force; so
making the solid, liquid; hence fusion. Again, this same
motion, yet more increasing, and thus causing a still wider
separation between particles, may drive them apart beyond
the reach of Cohesion; so changing the solid or liquid into
a gas or vapor; hence vaporization, as in boiling, etc.

Sources of Heat.—1st. The Sun, where it is possibly
maintained by the impact of solid bodies, scattered through
space, which from time to time must fall in upon the sun.
The heat from this source, shows certain properties of
intensity, which indicate a very high temperature in the
orb from which it proceeds.

2nd. Mechanical action, Friction, percussion, etc. It
has been proved by Joule and others, that a given amount
of mechanical action or motion is capable of producing a
given amount of heat, however the motion be applied.
Thus, the force or motion implied in the fall of one pound
weight, through 772 feet, is capable of evolving heat
enough to raise the temperature of one pound of water one
degree. This is known as "the equivalent of heat."

3rd. Electricity, when passing through a resisting me-
dium. E. g. Lightning, Electric sparks, Electric light, Pla-
tinum wire, ignited by a current, etc.

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4th. Chemical combination, including ordinary combustion. Examples of this are countless; thus the mixing of water with oil of vitriol, or with quicklime, or anhydrous sulphate of copper, develops great heat. So all cases of combustion.

The cause of the heat motions in all these cases is plain. In the 1st and 2nd, the *great* mechanical motion is converted directly into a series of *small* reciprocating motions or vibrations, i. e. "heat." In the 3rd, the resisted force, as it passes through, causes the resisting matter to vibrate, besides, in some cases, tearing off particles from the solid points between which it moves, so giving them also vibratory motion.

In the 4th, the different particles rushing together to unite, in like manner establish vibrations, by a similar mechanical action.

The ANIMAL HEAT generated in the bodies of living creatures, is simply one case of the 4th source, as it is produced by union of the oxygen absorbed by the blood in the lungs, with the effete matter, exhausted tissue, etc., found throughout the body. It is simply slow combustion, which, together with similar actions, such as the decay of wood in the air, has received the name of EREMAKAUSIS.

Fig. 10.

Measurement of Heat.

Thermometers. — Instruments for measuring heat. *The air thermometer* invented by Sanctorio, in 1626, consists of a glass tube and bulb, partly filled with air, dipping into a vessel of water. When heated, the air expands and the surface of the water falls in the tube ; when cooled, the air contracts and the water rises. This instrument is delicate, but difficult of adjustment for comparison of results.

The spirit thermometer, invented by a member of the Florentine Academy, consists of a capillary glass tube, with a bulb, partly filled with alcohol, otherwise vacuous, and hermetically sealed, and having a scale attached, divided into degrees, as will be presently described.

This instrument is much used for very low temperatures, but is useless above 150° F., as alcohol boils about 173° F.

The mercurial thermometer invented by Reaumur. This is exactly like the last, mercury being substituted for alcohol. In order that various instruments may be made to accord, two *fixed points* have been settled upon, the melting point of ice, and the boiling point of water. The height of the mercury corresponding to these being ascertained, the space between may then be divided into degrees, according to one of three scales now in use, the Fahrenheit, the Centigrade, the Reaumur. The first, F., divides the space into 180°, numbering the first 32° and the last therefore 212° (32 + 180 = 212.)

The second, C., divides it into 100°, numbering the first 0° and last 100°.

The third, R., divides it into 80°, numbering the first 0° and last 80°.

To convert degrees of one of these scales into those of another, the following formula may be used.

$$\text{Cent.} = \tfrac{5}{4} \text{R.} = \tfrac{5}{9} (\text{F.} - 32)$$
$$\text{Reau.} = \tfrac{4}{5} \text{C.} = \tfrac{4}{9} (\text{F.} - 32)$$
$$\text{Fahr.} = \tfrac{9}{5} \text{C.} + 32 = \tfrac{9}{4} \text{R.} + 32$$

A table showing at a glance the corresponding degrees, will be found in the APPENDIX, p.291.

Above and below the fixed points, the degrees are marked off by simple measurement, and comparison with those between. Degrees below the 0° of each scale are numbered progressively downwards, and are distinguished by the sign minus; thus the freezing point of mercury is —40° F.

Specific Heat.—We might suppose that the same amount of heat being applied to different bodies would raise them all to the same temperature; but this is not so. From the different arrangement of particles in various bodies, some require more force than others to develop a given velocity of movement. This difference of capacity for becoming heated, we call Specific Heat. In expressing it relatively, we assume water (which has the greatest of all bodies), as the unit.

Specific Heat of Solids and Liquids.

Water..	1.0000
Alcohol, sp. gr. = 0.81.....................	0.7000
Nitric Acid, sp. gr. = 1.29895.............	0.6613
Wood, in the average......................	0.4800
Sulphuric Acid, sp. gr. 1.605.............	0.3346
Sweet Oil..................................	0.3096
Lime......................................	0.2169
Sulphur...................................	0.2085
Glass.....................................	0.1929
Cobalt....................................	0.1498
Iron......................................	0.1098
Nickel....................................	0.1035
Copper....................................	0.0940
Tellurium.................................	0.0912
Antimony..................................	0.0507
Zinc......................................	0.0927
Tin.......................................	0.0475
Platinum..................................	0.0344
Bismuth...................................	0.0298
Mercury...................................	0.0290
Gold......................................	0.0288
Lead......................................	0.0281

The high specific heat of water is of great value in moderating the extremes of temperature and equalizing climate in the neighborhood of large masses of water. The excess of heat is there absorbed without rendering the water proportionately hot, and again emitted, without corresponding fall of temperature.

Specific heat of Gases and Vapors as compared with equal weight of Water.

Water...	1.00000	Marsh Gas...	0.59295
Air...	0.23741	Ether Vapor	0.47966
Oxygen...	0.21751	Alcohol Vapor.	0.45341
Hydrogen...	3.40900	Olefiant Gas.	0.40400
Nitrogen...	0.24380	Sulphurous Acid.	0.15531
Chlorine...	0.12099	Hydrochloric Acid...	0.18521
Bromine...	0.05552	Sulphuretted Hydrogen	0 24218
Carbonic Acid...	0.20246	Ammonia...	0.50836
Carbonic Oxide...	0.24500	Turpentine Vapor...	0.50610
Nitrous Oxide...	0.24470	Bisulphide of Carbon...	0.15696
Nitric Oxide...	0.23173		

A curious connection between the specific heat of bodies and their atomic weights was first announced by Dulong and Petit, and has been confirmed by Regnault, namely, that *the specific heats of elements are inversely as their atomic weights;* or that the products of these two quantities are constant. According to the experiments of Regnault, however, this " constant " may vary between 2.95 and 3.41.

We should, from this law, conclude that *the same amount of heat is needed to raise an atom of any element through a given number of degrees.*

In compound bodies the same law holds good, except that the constant varies with different classes of bodies. Thus, for the protoxides it is 5.64, for the sesquioxides 13.6, for the sulphides 4.92, for the carbonates 10.75, etc.

Effects of Heat. I. Expansion. — All bodies, with certain exceptions to be presently noticed, expand with an increase of temperature, and contract with a loss of heat. This expansion is, however, very various in different bodies, as will appear from the following table:

Linear Expansion of Solids between 32° and 212° F. for each degree.

White Glass............	0.00000478	Copper.................	0.00001092
Platinum.........	0.00000491	Bronze.........	0.00001009
Untempered Steel...	0.00000600	Brass, Cast............	0.00001043
Cast Iron..............	0.00000618	Silver........	0.00001060
Wrought Iron.........	0.00000656	Tin......................	0.00001207
Tempered Steel......	0.00000689	Lead.....................	0.00001850
Gold.....................	0.00000815	Zinc.	0.00001633

Cubic Expansion of Liquids between 32° and 212° for each degree F

Mercury..................	.000085	Common Oil.............	.000444
Water.....................	.000258	Alcohol or Nitric	
Sulphuric Acid.........	.000330	Acid	.000633
Oil of Turpentine or			
Ether...................	.000380		

Cubic Expansion of Gases between 32° and 212° for each degree F.

Air...	0.00203111	Hydrochloric Acid...	0.00204511
Hydrogen	0.00203766	Cyanogen...	0.00204561
Nitrogen	0.00203788	Carbonic Acid...	0.00204977
Sulphurous Acid......	0.00203866		

From this it appears that the expansion of various gases is practically the same.

At temperatures above and below those mentioned in the foregoing tables, the rate of expansion varies slightly with different substances, increasing with the rise in temperature, and decreasing with the reverse; but these changes are not of sufficient importance to be here dwelt upon.

A great variation is also found at those temperatures where the body changes its form, as from liquid to solid; and, in the case of water, this amounts to a reversal of the rule. Between the melting point, 32° and 40°, water *contracts* as it grows hotter, so that its maximum density is at that point, i. e. 40°; growing less by change of temperature either way.

The tables above given hold good both ways; bodies contracting when lowered in temperature, just as they expand when raised.

The close equality in expansion of glass and platinum is of great value, enabling us in constructing apparatus to directly weld or join these substances without risk of fracture through change of temperature.

Applications of expansion and contraction are countless. Shrinking tires on wheels, iron wheels on axles, etc.; drawing up the falling wall of the Conservatoire des Arts et Métiers; compensating pendulums and balance-wheels; thermometers of all kinds; testing strength of steam boilers easily and safely, by filling *full* with water, closing all valves, attaching pressure guage, and *warming;* air engines, etc.

Effects of Heat. II. **Fusion.** — Solid bodies heated to a certain point, begin to change their form, and to become liquid, excepting, of course, such compounds as suffer decomposition before this *fusing point* is reached. The temperature at which this change takes place differs greatly with different bodies, but is unchangeable for each, except as it is slightly affected by great changes of pressure. Thus, under pressure of 100 atmospheres, the melting point of paraffine is raised $6\cdot3°$, and of spermaceti $3\cdot6°$ F. The melting point of ice, however, is lowered by pressure, so that it may become liquid under pressure, and solidify on the relief of the same. This explains the phenomena of "regelation," and the motion of glaciers. See Tyndall on Heat as a Mode of Motion, page 208.

The fusing point of different substances will be given hereafter, where their various properties are described under the head of Chemistry.

Latent Heat of Liquids. — We observe by experiment that a large amount of heat is required to convert a solid into a liquid, without producing any effect in changing its

temperature. Thus, if a pound of ice at 32° is mixed with a pound of water at 176°, the ice will be melted, and we shall have two pounds of water at 32°; all the additional heat in the water (144°) having been absorbed by the ice, without, however, any increase to its temperature, but with simply a change in its state. Heat so absorbed we call "latent heat."

This phenomenon should be expected from our theory. A certain amount of force, in the shape of heat-motions, or vibrations, must be expended in overcoming the polar force between the particles, and thus changing the state of the body.

This latent heat varies with different bodies, as will be seen from the following table, in which the number shows how many degrees, the heat absorbed in fusing the given substance, would raise the same after liquefaction.

Water	142.65	Bismuth	22.75
Nitrate of Soda	112.98	Sulphur	16.86
Zinc	50.63	Lead	9.66
Silver	37.92	Phosphorus	9.05
Tin	25.65	Fusible metal*	8.10
Cadmium	24.58	Mercury	4.93

This latent or absorbed heat, is absolutely necessary to the change of form from solid to liquid; hence if in any way this change is effected without giving this required heat, the body will, or must, lose a corresponding amount of its own heat or heat motion, having in this case performed this work of change, by and at the expense of its own internal motive power or heat vibrations, and it must therefore fall in temperature. This is the theory of " FREEZING MIX-TURES." Certain bodies if mingled become liquid, by reason of certain attractions among their particles, they consequently absorb heat motions in effecting this change, and fall in temperature. Some of these bodies, and the descents

* 1 Lead, 1 tin, and 4 bismuth.

accomplished by rapidly mixing them, are given in the following table.

Sulphate of Soda	8	$+50°$ to $+2.$
Hydrochloric Acid	5	
Pounded ice or snow	2	$+32°$ to 0.
Common salt	1	
Sulphate of Soda	3	$+50°$ to $-2.$
Dilute Nitric Acid	2	
Sulphate of Soda	6	
Nitrate of Ammonia	5	$+50°$ to $-14.$
Dilute Nitric Acid	4	
Phosphate of Soda	9	$+50°$ to $-20.$
Dilute Nitric Acid	4	

Such preparations as the above are often used; in chemical operations, where a very low temperature is required, as in preparing liquid sulphurous acid, in surgery, and in culinary processes, as in the preparation of ice-cream. In all cases the more finely the ingredients are pulverized, and the more thoroughly they are mixed, the lower the temperature reached. It must also be remembered that the fluid obtained, is far colder than the solids employed, and is indeed the efficient source of refrigeration and must not therefore be drained off or allowed to escape, until it has done its work.

Freezing. Congelation.—As we might naturally expect, when the action last discussed is reversed, and heat is abstracted from a liquid, it will at a certain point, begin to change its form and become solid. We might also suppose that the point at which this change took place, in any substance, was the same either way. This is indeed so as a rule, but not under all conditions. Thus, if water, deprived of air, is kept absolutely at rest, it may be cooled to 11° without freezing; then, the least shock or jar, will cause it to freeze in an instant. So a concentrated hot

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solution of sulphate of soda, cooled at rest and out of con-
tact with air, remains liquid indefinitely, until shaken or
exposed to the atmosphere.

In becoming solid, the liquid develops as much heat as
it abstracted in becoming liquid; this is shown in the case
of the water by the immediate rise in temperature of the
whole material to 32°, on the freezing of part, and in the
case of the sulphate of soda, by a notable heating.

In all ordinary cases, moreover, we find that while we
are freezing or solidifying any liquid, its temperature does
not fall, during the whole process, though heat is being
abstracted from it at a rapid rate.

Expansion in Freezing.—At the moment of passing from
the liquid to the solid state, most substances expand. This
is very notable in water, which increases to 1.075 times
its bulk at 40°; hence ice floats on water. This expan-
sion takes place with such force as to burst even strong
iron vessels, and, under very heavy pressure restraining
this expansion, according to M. Mousson, water will not
entirely solidify.

Like water, cast-iron, antimony and bismuth, expand in
solidifying; mercury, phosphorus, stearine, etc., contract.

Effects of Heat. III. Vaporization. — Liquids when
heated to a certain point, begin to change their state, and
to pass into the condition of gases. The temperature at
which this change takes place, differs greatly with differ-
ent substances, though it is the same for the same body,
under the same conditions; but it is largely affected by
changes of pressure, the nature of the containing vessel,
etc. The phenomenon alluded to, is commonly called BOIL-
ING, and the temperature at which this action begins, is
called the "*boiling point.*" The boiling points of various
bodies will be stated hereafter, in connection with their
other properties.

The effect of a change in pressure, on the boiling point of water, will be seen from the following table.

Water, boiling in the open air, is under a pressure of about 15 lbs. per sq. inch (or such as would be given by a column of mercury 30 inches high), due to the weight of the atmosphere. Under this condition its boiling point is 212° F.

Under pressure of				Its boiling point is
0.200 ins. of mercury =	0.098 lbs. pr. sq. in. =	0.006 atmospheres		32°
0.524	=	0.257	= 0.017	"	60°
1.000	=	0.490	= 0.033	"	80°
1.860	=	0.911	= 0.062	"	100°
.7420	=	3.636	= 0.247	"	150°
15.150	=	7.420	= 0.505	"	180°
30.000	=	14.700	= 1.000	"	212°
61.200	=	30.	= 2.	"	251.6°
91.800	=	45.	= 3.	"	276.4°
122.400	=	60.	= 4.	"	295.6°
153 000	=	75.	= 5.	"	311.2°
183.600	=	90.	= 6.	"	324.3°
214.200	=	105.	= 7.	"	335.8°
244.8	=	120.	= 8.	"	345.8°
275.4	=	135.	= 9.	"	355.0°
306.0	=	150.	=10.	"	363.4°
387.2	=	180.	=12.	"	378.4°
612.0	=	300.	=20.	"	420.3°
1223.0	=	600.	=40.	"	487.0c
2038.	=	1000.	=66.6	"	548.0c

From this table, various conclusions may be drawn. The boiling point varies less and less with the pressure, as it ascends. Thus, the change of less than one atmosphere makes a difference of 180° in the boiling point between 32° and 212°, while it makes a change of but 39° between 212° and 251°, and of but 25° between 251° and 276°, etc. These points of pressure and temperature being inseparable, one may serve as a measure of the other.

A liquid inclosed in a tight vessel, will generate a pressure corresponding to its temperature. If in any way this pressure is relieved, the liquid will boil violently, because heated above its boiling point for this lesser pressure. This is well illustrated by the Culinary Paradox.

Fig. 11.

Here a glass, containing water in the act of boiling, is corked and inverted. If now cold water is poured over the flask, the vapor or steam contained will be condensed, the pressure thus relieved, and the water made to boil violently. The same thing is proved by various experiments in freezing by evaporation, to be presently described. This fact is again usefully applied in the manufacture of sugar.

The pressure of the atmosphere varies at different heights; this effects the boiling point of water, and thus we may, with a *thermometer*, measure the height of various locations. A change in boiling point of 1° indicates a change in height of 600 feet. On Mt. Blanc water boils at 183°, and at Quito at 194°.

For tension of various vapors at different temperatures, see Regnault's Tables, Fr. Inst. Jour., Vol. XV., pp. 136, 207, 278, 356, and 437; Vol. XVI., pp. 48, 115, 186, 257, 328, and 388; Vol. XVII., p. 50, 114, and 190; Vol. XL., p. 241.

The change in volume which accompanies the change of a liquid to the gaseous form, is very great, varying, however, with the pressure; the volume of steam, like that of any other gas, varying inversely with the pressure applied. At the ordinary atmospheric pressure, however, water expands 1694 times in becoming steam. In round

numbers, a cubic inch of water makes a cubic foot of steam.

The nature of the vessel containing the liquid, has a marked effect upon its boiling. A vessel offering strong adhesion to the liquid, and no points from which bubbles of steam can be readily disengaged, raises the boiling point, and renders that action violent and spasmodic. Thus, water in a smooth and clean glass flask, may be raised to 222° before it boils.

A few scraps of metal, or even angular bits of glass, will lower the boiling point to its normal state, and moderate the violence of the action.

Water deprived of air, boils also with difficulty and violence. In fact, Grove, from many experiments, concludes that if water could be entirely deprived of all gas (a result never yet attained), it would not boil till heated hot enough to cause its decomposition. See Proceedings of the Royal Institution, 1864, p. 166.

Latent Heat of Gases. — As in the conversion of solids into liquids, so also in the conversion of liquids into gases, we observe that a large amount of heat is expended in effecting this change, without any influence upon the temperature of the body in question. This fact likewise accords with our theory, as before. The lost or latent heat is but so much heat-motion expended in overcoming the cohesive force, which kept the body in its liquid form.

The latent heat of different gases or vapors, varies greatly, that of water or steam being the highest. Thus, the heat required to convert one pound of water into steam, would raise a pound of water otherwise through 972 degrees. With other bodies it is as in the table.

Water	972.	Ether	162.
Alcohol	374.	Turpentine	133.
Acetic Acid	183.		

3 *

Where differences of pressure are introduced, the latent heat varies, decreasing with the increase of pressure, and consequent rise of the boiling point.

As we have already noticed with the latent heat of liquids, so with gases, if the change of state is accomplished without a supply of extraneous heat, heat must be supplied and lost by the changing body itself. We may regard the liquid particles as possessing motions or heat vibrations, tending to throw them beyond the range of cohesion, but not yet sufficiently powerful to overcome that force. Hence, they vibrate within their boundaries like a pendulum, restrained, but without loss of motion, thus preserving their temperature. If now a little additional force is given them, just enough (with what they possessed) to overcome cohesion, they break their bounds, but, in doing so, have spent their force, and (like a pendulum which has just been able to break from its support) fall motionless, or nearly so, into their new state. In other words, lose much of their heat motion and become "cold." All cooling or freezing by evaporation is of this kind. A striking instance is as follows:

If a little water in a small dish is supported over a larger one containing oil of vitriol, both being under the exhausted receiver of an air-pump; the boiling point of the water will be so low, under the diminished pressure,

Fig. 12.

that this action will go on at the ordinary temperature, and (the vapor formed being absorbed by the oil of vitriol) will continue. But the water, passing into vapor, destroys or renders latent much heat motion, it therefore becomes cold, and cools the water from which it rises, until finally the latter is frozen by its own evaporation. We may thus

have the strange anomaly, of water, at once *boiling and freezing*, practically realized.

On the same principle operates the Cryopherous of Wollaston, consisting of two connected bulbs containing some water, and exhausted of air. All the water being turned into one bulb, and the other placed in a freezing mixture; the vapor within is thus condensed as fast as it forms, and the water from which it rises is quickly frozen, as before, by its own evaporation.

A more practical application of the same general principle, is furnished in the freezing apparatus of Carré.

Fig. 13.
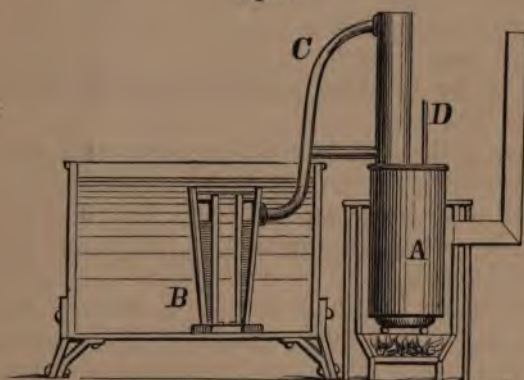
This consists of two strong wrought-iron vessels, A and B,* connected by a tube C, the whole exhausted, and closed air-tight. A contains strong aqua ammonia, and is placed in a furnace, where it is heated until a thermometer, set in an oil tube D, indicates a temperature of 270° F., B, in the meantime, being immersed in water at the ordinary temperature. By this means the ammonia is driven out of the water in A, and is condensed under a pressure of $6\frac{1}{2}$ atmospheres into a liquid form in B. A

* B. is shown in section.

is then removed from the furnace and plunged into the water which before surrounded B, while the vessel containing the substance to be frozen is placed in the opening in B, a little alcohol being poured into the space between to prevent it from freezing fast. The pressure being relieved by the cooling of A, the condensed ammonia in B boils, and its vapor being rapidly absorbed in the now cold water in A, this action is kept up, causing a rapid loss of heat in B. With the small apparatus sold in Paris for 100 francs, the heating occupies about 30 minutes, after which, with care, two cans full of water (about 2 quarts) may be frozen into solid ice. This apparatus may be applied to domestic uses. On the large scale it has been so constructed as to be continuous in its action, and has been reported upon favorably by the French Academy. See Journal of the Franklin Institute of Pennsylvania, Vol. 48, page 109.

Evaporation is the term by which we designate the gradual vaporization of a liquid at its surface, which may take place at any temperature. Example, Drying of a wet cloth. This action, like vaporization, implies a great absorption of latent heat. Thus masses of water are but little affected by the heat of summer, and the body in like manner by the evaporation of perspiration from its surface is saved from an injurious elevation of its temperature, even when exposed to intense heat. Thus Dr. Fordice, Sir Joseph Banks, and others, sat for half an hour in an oven with a joint of meat which was cooked during the time.

Condensation. — When the action described in vaporization is reversed, and the temperature of a gas is lowered, a point may at last be reached, at which it will change its state, and become liquid. *This change of a gas into a liquid by loss of heat is called* CONDENSATION: *when assisted by pressure, it is termed* LIQUEFACTION.

The temperature at which this change takes place is identical with that at which the reverse change happens, in each substance; in fact *its boiling* point, and as might be expected, the latent heat expended in the reverse change is redeveloped in this. Thus a pound of steam, at 212°, would give out in passing into the state of water, at the same temperature, as much heat as would raise a pound of water through 972°, or 972 pounds of water through 1°.

Distillation.—By combining the two processes of vaporization and condensation, we may effect the separation of substances having different boiling points, when these are mixed. This operation is called distillation. We place the mixture in a closed vessel called a retort or still, and there heat it, until the more volatile body is vaporized; the vapor formed is carried directly into a condenser, receiver, worm, or the like, where it is cooled, and so rendered liquid. The more volatile body is thus separated from that which is less so, and which remains in the retort or still, not being heated to its boiling point. It must be remembered, however, that the less volatile body will, in these conditions, *evaporate*, and that thus portions will pass over with the other. A complete separation cannot, therefore, be thus obtained. Alcohol will, for example, carry over with it at least fifteen per cent. of water, and mercury a notable quantity of gold, even, as well as other metals.

Sublimation is the term applied to a like action, when the substance treated is a solid, which passes into the gaseous state, directly or after fusion, and likewise back into the solid form. Example, purifying sulphur, iodine, etc.

Transfer of Heat. — Heat may pass from place to place, and body to body, in one or other of three ways, i. e., by Conduction, Convection, or Radiation.

Conduction is the transfer of heat by means of particles

in contact. E. g. The end of a poker being put in the fire, the handle will, in time, become heated, by conduction, through the iron itself. This power of conduction belongs chiefly to solids, and varies greatly in different substances, as will appear from the following table:

Table of conducting powers of Solids.

Gold	1,000	Tin	302.9
Silver	973	Lead	179.6
Copper	898	Marble	23.6
Iron	374	Porcelain	14.2
Zinc	363	Clay	11.4

From this it follows, that whenever we wish to promote the transfer of heat, we should use good conductors, as in culinary vessels, steam boilers, and the like; while for the prevention of this transfer, bad conductors should be employed, as in ice-houses, winter clothing, handles of tea-kettles, etc.

Fig. 14.

Conduction takes place with great difficulty IN LIQUIDS. Thus, if an air thermometer is placed in a liquid, as in the drawing, and this is strongly heated at the surface, by a hot iron, very little effect will be produced upon the thermometer, at a short distance below.

The conducting power of gases is probably even less than that of liquids, though owing to their great mobility and diathermancy, this is hard to demonstrate directly. The efficiency of double sashes, double walls, in iron furnaces, and the like, however practically indicates this, as does also the following phenomenon.

The spheroidal state. — By this term we indicate the condition of a liquid, when thrown upon a solid body, heated considerably above the boiling point of the former;

when it is lifted out of contact with the solid, by vapor first formed, and then remains floating upon this cushion of steam, which is supplied as it escapes, by *evaporation* at the lower surface, and protects the liquid from any great accession of heat, so that this is never raised to its boiling point. This is well shown by dropping water over an inverted red-hot platinum dish, properly focussed in a magic lantern, and watching the image on a screen. If liquid sulphurous acid is employed, water may be frozen in a red-hot crucible; or with solid carbonic acid and ether, mercury even can be frozen in the same situation. The non-conducting state of the vapor is clearly necessary to the above condition.

Fig. 15.

By reason of this same action, the hand is protected if placed for a moment in a stream of molten iron, gold, or the like; the skin being shielded by a non-conducting layer of vapor from the burning fluid. This fact explains some conjurers feats, and many of the famous ordeals.

For the production of this spheroidal state, a certain temperature is required; hence the value of the test applied by the laundress to her flat-irons. If the water runs off in drops without boiling, the iron is hot enough.

Convection. — This term describes the transfer of heat by particles in motion — as thus: Heat being applied to the bottom of a vessel of water, the lower particles of the fluid become hot, are consequently dilated, and giving place to cold, and therefore denser particles rise, carrying their heat into other parts of the vessel.

This mode of transfer can only exist in liquids and gases, whose particles are mobile, and is in fact the means by which masses of such bodies become heated throughout. The currents thus established are easily shown

in water, by a little powdered amber mixed in the liquid, and in air by smoke or dust.

Fig. 16.
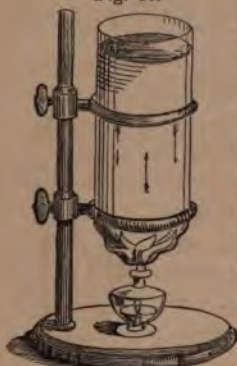
In all cases of heating such substances on the large scale, as in steam boilers, house furnaces, etc., it is very important that the tendencies of these currents should be studied, and their maintenance and regularity carefully provided for. To such currents we owe the draught of chimneys, the ventilation of buildings, the trade, and other winds, many great ocean currents, etc.

Radiation.—By this term we indicate the transfer of heat, by motions of the nature of undulations, or vibrations, in a certain mobile fluid, pervading all space, called the luminiferous æther. This impalpable fluid or gas is incapable of any direct physical test, but is believed (for the very strongest indirect reasons) to exist, and to be not only the vehicle of heat, but that also of light, whence its name luminiferous, or "light bearing." A hot and cold body placed at a distance in a vacuum, will rapidly become equalized in temperature; the one gaining, the other losing heat. We suppose, in this case, that the motions of the hot body have communicated vibrations to the æther, which this has in turn conveyed to the colder.

Heat propagated by this means is reflected, refracted, absorbed, polarized, etc., exactly as is light, and may, in fact, be regarded simply as slowly moving (in the sense of vibrating) light. This, however, will be more fully discussed, page 111.

Radiant heat is best reflected by planished surfaces of metal, and best absorbed by dull, rough surfaces, such as lampblack. It is also absorbed in very different degrees,

by gases and vapors, and by certain solids and liquids. This absorption varies, however, with the character of the radiant heat, as regards its intensity, heat from hot iron at 500° passing where that from water at 200° would not.

Rock salt is the most "*diathermanous*" solid known, and offers equally little resistance to heat of all intensities. It is by radiation that the sun's heat reaches us, or that of a fire, before which we stand, etc.

LIGHT.

By the word Light we indicate the cause of that sensation, affecting the eye, when it is turned upon the sun, stars, a burning body, or the like.

This cause, we have every reason to believe, is identical in its nature with heat; that is, we believe it to be simply a very rapid vibratory movement among the particles of ordinary matter, and the luminiferous æther already mentioned, which pervades all space, and most bodies (and which, though too rare and fine to admit of any direct measurement or physical testing) is yet abundantly capable of producing those phenomena which we attribute to its agency. In fact, the conclusions which these phenomena themselves lead us to draw, respecting its lightness and mobility, forbid us to expect that, with the rough means at our disposal, we should be able in any direct way to test or examine it.

The difference between heat and light consists simply in the rapidity of the motions or vibrations producing them. If these number between 450 billions and 780 billions per second, they constitute light: if less than the first, they are heat: if more than the last, they ·are *actinism*. See page 54.

Sources of Light.—As might be expected from our theory,
4

all sources of heat are, or may become, if intensified, sources of light. Thus we have, 1st, the Sun. 2nd. Mechanical action. E. g. Flint struck in a vacuum, Perkins' iron wheel revolving 6000 times a minute, and touched with a steel file, Fig. 17. 3rd. Electricity. E. g. Sparks, lightning, aurora, electric light, glowing wire, etc. 4th. Intense chemical action. E. g. Combination of iron and sulphur, phosphorus and iodine, ordinary combustion, etc. 5th. Phosphorescence. E. g. Glowworms, fire-flies, etc. In all these cases the "light vibrations" are developed exactly as those of heat—by the same actions.
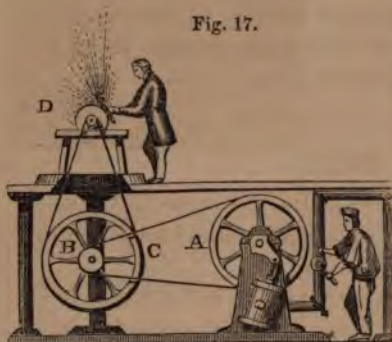
Fig. 17.

Propagation of Light. — Light emanates from all luminous bodies in straight lines, radiating from every luminous point. It passes without loss or change through free space, but is variously acted upon, and changed in its direction and character when traversing different bodies. These changes we shall study in their order presently.

The Velocity of Light in free space is 190,000 miles per second. This Roemer proved by observation of the eclipses of Jupiter's first satellite, in 1675, and Foucault demonstrated experimentally with a very ingenious apparatus, by which he was able to prove that the velocity of light was less in water and dense media, than in air and other rare ones. Since light is projected in

Fig. 18.

straight lines, an opaque body, placed before a source of
light, will cut off its rays from a certain space. This
space, so deprived of light, we call the shadow. Thus, A,
Fig. 18, being a source of light, and B C an opaque body, the
indefinite space, B C E D, is
its shadow. If the source
of light is a point, or at a
vast distance from B C, this
shadow will be definitely
bounded by B D and C E;
but if the source of light con-
sists of many points, or an

Fig. 19.
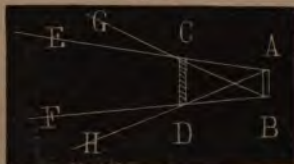
extended surface, A B, Fig. 19, then there will be a full
shadow, C D E F, where no light enters, and around this
as *penumbra*, or gradually decreasing shade, G C E, and
F D H, from which is excluded the light of some
only, among the luminous points in A B.

Interference.

Though, as a general rule, rays of light, like sounds,
may cross each other in all directions, without any inter-
ference or mutual disturbance, yet in certain cases inter-
ferences may occur. Thus, if two rays are brought
together in such a way that the rising phase in the
vibrations or waves of one, corresponds with the sinking
phase of the other, their opposite motions will be mutually
destructive; the light motion will cease, and the light will
disappear. Two rays of *light* may thus unite to produce
darkness. If, however, the two waves of light *coincide*
in phase of motion, a double brightness is the result.
This action has the most exact parallel in sound, and in
undulations of liquids, etc. Thus, an opening like figure
20 being made between two rooms, a sound produced in
one of them will not be heard in the other, unless one of
the two openings, *c d*, is closed; because the sound waves

coming through the two passages, and meeting in different phases, effect a mutual destruction. We shall have frequent cause to refer to this subject of interference.

Fig. 20.

But at present we shall confine ourselves to one case. Two adjacent cones of light, proceeding, for example, from two pinholes near together in a card, produce on a screen, at a short distance, a series of dark and light bands in homogeneous and colored fringes in mixed or white light.

Diffraction. — By this term we indicate the effect produced on light, in passing across the edge of an opaque body. In this case a new system of undulations is developed in the æther, having the solid edge as their centre. These, by their interference with the original rays, produce fringes of light and darkness (or color with mixed light) within and without the geometric shadow of the solid edge. Wires, gratings, etc., act in the same way.

Reflection. — When a ray of light falls upon a polished surface, it is thrown off again at an angle the same as that of its incidence. This may be well shown as follows: The mirror, M, being so adjusted that a ray of light from any source is thrown down through a diaphragm, N, upon a polished horizontal surface, n; this ray will be reflected upward, and will fall upon the little movable screen, P, when this is so adjusted, as to make the angle A n P equal to the angle A n N. From this it follows, that parallel rays, falling on a plane polished surface, are reflected in parallel lines (see Fig. 22), and that diverging rays are reflected with

Fig. 21.

Fig. 22.

Fig. 23.

the same divergence as before, the only change being, that they now seem to diverge from a point as far below the reflecting surface as their actual source is above it. (See Fig. 23).

If, therefore, we are not aware of the reflecting surface, we may suppose the light to come, not from its true source, but from this supposed or equivalent source, behind the reflecting surface.

This principle has been applied in Dr. Pepper's theatri-

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cal arrangement for "the ghost." A large sheet of plate
glass, A B, without silvering, is fixed near the front of

Fig. 24.
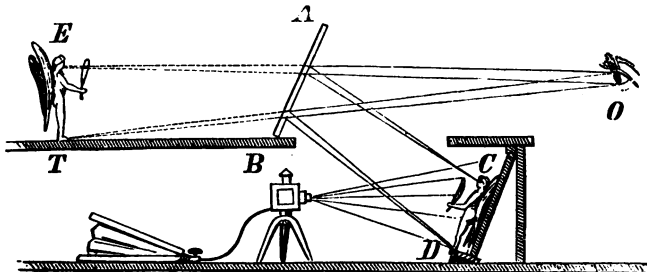
the stage. The "ghost," brightly illuminated by a lime-
light, is placed at C D, and the rays of light passing from
this figure through the trap door, C B, and reflected from
A B, enter the eyes of the audience at O, just as if they
came from a similar figure standing on the stage at E T.
The mirror may also be placed at an angle across the
stage, and the "ghost" reflected from behind one of the
wings.

If the reflecting surface is curved, parallel rays falling
upon it at different places, will make with it different
angles, and, hence, will be reflected in dif-
ferent directions.

Fig. 25.
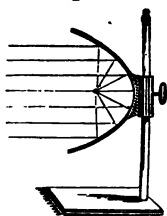
If the reflecting surface is of parabolic
form, then parallel rays falling on it will
be reflected to one point, called its focus,
and reciprocally a source of light being
placed in this focus, its rays are all
thrown out in parallel lines.

The reflecting power of different bodies
is very various, and changes with the angle of the inci-
dent light. Transparent bodies, such as glass, at certain
angles, allow part of the light to be transmitted, and part

to be reflected. This last increases with the obliquity un
til a certain point is reached, called the angle of total re-
flection, when *all* is reflected, and the body is, as it were,
absolutely opaque.

The following table illustrates the relative reflecting
power of a few substances at different angles.

The incident light making angles with the surface of

	5°	15°	30°	60° to 90°
Water........................	72	21	6.5	1.8
Glass (1st surface)......	54	30	11.2	2.5
Black Marble, polished	60	15.6	5.1	2.3
Mercury as on Mirrors	70	15.6	5.1	60.

Unpolished surfaces, by reason of their minute, invisi-
ble, but countless irregularities, reflect the light they
receive in all directions; or, in other words, disperse it,
thus becoming, in this respect, similar to luminous bodies.
Part of the light received is of course, however, absorbed,
even if the body is white; and if it is colored, it must
absorb all those colors which it does not give back. Thus,
a red body absorbs all the colors but red, a green one all
but green.

When the reflecting surface is corrugated very finely,
as is the case with mother of pearl, fine rulings on glass,
etc., the reflected rays from adjacent ridges (being very
little separated), will *interfere* and produce (in mixed or
white light), colored fringes, or, as it is called, *"iri-
descence."* All visible, non-luminous objects also reflect
light, but from extreme irregularity of surface, presenting
all angles to the incident ray, they throw it off in all
directions, like luminous bodies.

Reflection will not only take place at the surface of a
dense medium, but also of a rare one. Thus, an object
may be seen reflected from below a surface of water,
where we may regard the air as the reflecting surface

(see Fig. 26), or from the rear surface of a plate of glass, where the same is true. So, also, a ray of light, passing

Fig. 26.
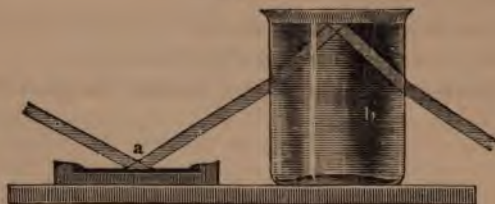
out with a vein of flowing water, will be reflected back and forth from the interior surface of the water, thus following the stream and illuminating it, and seeming to bubble up where the stream breaks.

By an extensive application of this principle, the beautiful experiment of the illuminated fountain is arranged, the jets being lit up by two powerful lime or electric lanterns, one immediately below, and the other directly above them.

If light falls obliquely on a very thin plate, as in a soap

Fig. 27.

bubble, film of oil on water, etc., the rays reflected from the first and second surfaces, may interfere, being very little apart (see Fig. 27), and thus produce, with mixed or white light, colors dependent upon the thickness of the film, as will be explained further on. The rays which pass through

Fig. 28.

will also suffer interference from those twice reflected within the plate, so giving us the same effect by transmitted, as by reflected light. The film may be of a rare substance, as air inclosed be-

tween two plates of glass. If this air film varies in thickness regularly around a centre, as when it is produced by placing a lens upon a plate of glass it will develop, with white light, concentric rings of color. These are known as Newton's rings. The apparatus for producing them is shown at Fig. 28.

Refraction.—A ray of light, coming obliquely upon the surface of a body more or less dense than that through which it was before passing, is bent from its course, and passes on in a new direction. This bending is called refraction.

Where the ray passes from a rare to a dense body, it is bent inward towards the latter; in passing from dense to rare this is reversed. In other words, the path of the ray would be the same whichever way it went; or if it passes through a dense or rare body with parallel faces, it will simply be displaced, not changed in its direction. (See Fig. 29.) If the opposite sides of

Fig. 29.

the body were not parallel, however, its direction would be changed (see Fig. 30).

Fig. 30.

The amount of this bending differs with different bodies, and also with the angles of the incident rays. The relative refracting powers of different substances, are indicated by certain numbers, called "INDICES OF REFRACTION." These are determined by experiment. See Table.
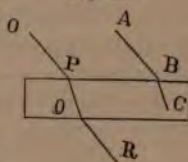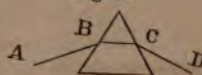
Table of Indices of Refraction. — Solids.

Chromate of Lead...	2.50 to 2.97	Zircon..................	1.95
Diamond..............	2.47 to 2.75	Borate of Lead......	1.866
Phosphorus	2.224	Carbonate of Lead..	1.81 to 2.08
Glass of Antimony.	2.216	Ruby...................	1.779
Native Sulphur......	2.115	Felspar.....	1.764

T.)urmaline..	1.668	Spermaceti	1.503
Topaz, colorless	1.610	Crown Glass	1.500
Beryl.........	1.598	Sulphate of Potash	1.509
Emerald.........	1.585	Sulphate of Iron.	1.494
Flint-glass......... ...	1.57 to 1.58	Tallow, Wax.....	1.492
Quartz..	1.547	Sulphate of Magnesia......	1.488
Rock Salt.	1.545	Iceland Spar.........	1.654
Rosin	1.543	Obsidian.	1.488
Sugar...................	1.535	Gum Arabic.........	1.476
Phosphoric Acid ...	1.544	Borax	1.475
Sulphate of Copper	1.53 to 1.55	Alum......	1.465
Citric Acid...	1.527	Fluor-spar.....	1.436
Nitre..	1.514	Ice	1.310

Liquids.

Bisulphide of Carbon	1.678	Nitric Acid, 1·48	1.410
Oil of Cassia.........	1.631	Sol. Caustic Potash, 1.41..	1.405
Oil of Bitter Almonds......	1.603	Hydrochloric Acid...........	1.410
Canada Balsam..............	1.528	Sol. of Common Salt	1.575
" Linseed	1.485	Alcohol, rectified.............	1.372
" Naphtha, rapeseed	1.475	Sulphuric Ether..............	1.358
" Olive...................	1.470	Sol. of Alum.....	1.356
" Turpentine.........	1.470	Blood	1.354
" Almond.....	1.469	Albumen, White of Egg....	1.351
" Lavender............	1.467	Distilled Vinegar.............	1.372
Sulphuric Acid, 1·7.........	1.429	Water	1.336

Gases.

Air	1.000294	Hydrochloric Acid	1.000449
Oxygen...............	1.000272	Carbonic Oxide..........	1.000340
Hydrogen...........	1.000138	Carbonic Acid...........	1.000449
Nitrogen	1.000300	Cyanogen.....	1.000834
Chlorine...................	1.000772	Olefiant Gas........	1.000678
Nitrous Oxide	1.000503	Marsh Gas.................	1.000443
Nitric Oxide	1.000303	Hydrochloric Ether.....	1.001095
Ammonia......	1.000385	Sulphuric Ether........:	1.900153
Sulphuretted Hydrogen	1.000644	Sulphide of Carbon.....	1.000150

To obtain the actual refraction for a given ray by a given substance, we have this rule. The sine of the angle of the ray after refraction, equals the sine of the angle of the incident ray divided by the refractive index of the body in question. Thus, suppose an incident ray, A B, whose sine is

C D, then the sine, G O, of the angle, E B G, which the ray makes after entering the dense body, X Y, is equal to C D divided by the index of refraction of X Y.
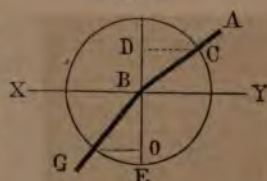
Thus, if X Y is flint-glass, OG=CD÷1.6 this being the index of refraction of this substance. We have already seen, that if the opposite surfaces of a refracting medium are not parallel, the direction of a ray passing through will be changed. (Fig. 29.) It is moreover evident that if these surfaces, one or both, are curved, the rays falling upon them will be more or less converged towards a point, or diverged and scattered, according as the curve or curves are convex or concave. See figures 32, 33 and 34. If now all these curves should be elliptical, the following results would be accurately attained.

Fig. 32.
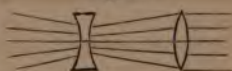
Fig. 33.

Parallel rays falling upon a convex lens would all be converged and collected at a certain point O, Fig. 35, which is called the "FOCUS." The distance C O is called the "FOCAL DISTANCE." This is fixed for the same lens, but differs with the material and

Fig. 34.
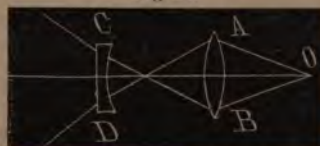
curvature of different lenses. We can roughly determine
this for any lens, by holding it
up at some distance from a
window, and finding how far
from it a sheet of paper must
be held, to receive a sharp
image of the same. This will
be the focal distance.
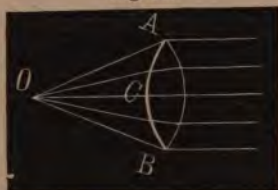
Fig. 35.

If instead of parallel we have
divergent rays coming upon
the lens, say from C, outside of the focus O', they can-
not, of course, be collected
at so near a point as O,
but yet will be centered
at some more distant one
C'. If C comes nearer
to O', C' will be further
off from O. These points
C and C' are called "conjugate foci," and of course admit
of an infinite variety of values in the same lens, though
always having a fixed inverse relation to each other. If
C corresponded with O', the rays would emerge from
the lens parallel, and thus have no focus. If C were
inside of O', the emerging rays would diverge. A con-
cave lens reverses all the actions of a convex one.
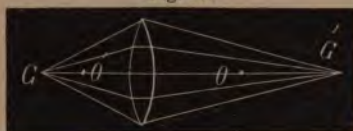
Fig. 36.

Formation of Images by Lenses. — Again, if rays from

Fig. 37.
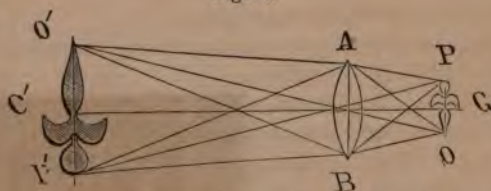
points not in the line C C', such as P and O come upon
the lens A B, they will be focussed at certain points P'

and O′, bearing the same relation to P and O that C′ does to C. We shall thus have an image formed at O′ P′ of luminous or illuminated object, differing in size, as the conjugate foci differ in distance from the lens. So that a small object, brought near to the lens, will make a large image at a distance, while a large body at a distance will make a small image close to the lens. E. g. For the first, the solar or gas microscope and magic lantern; for the last, the camera obscura. The image, as we see, will be inverted. This image may be again magnified by another lens placed beyond O′ P′, Fig. 37.

Spherical Aberration. — All that we have said would be strictly true of lenses whose curves are elliptical or hyperbolic; but in practice such lenses cannot be constructed; their curves must be spherical. Now with spherical lenses the rays passing through the edges are more refracted than those traversing the central portion, and are therefore focussed at a nearer point. Hence, the clear image, C D, made by the central rays would be obscured by the scattered light, O P, from the edges, and likewise with the image of the border rays. With a single spherical lens we cannot obtain a perfectly sharp image, owing to this,

Fig. 38.

which is called "spherical aberration."

By the combination, however, of two or more lenses of different curvature, this difficulty is overcome. For details, see Brewster's optics. We have the following forms of lenses in common use: A, Plano convex; B, Plano

Fig. 39.

E D C B A

5
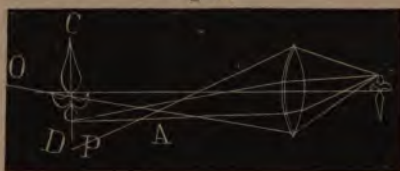
concave; C, Double convex; D, Double concave; E, Meniscus.

Double Refraction. — When a transparent solid is subjected to pressure or strain in one direction, it splits or separates an incident ray into two, one of these being refracted according to the laws already expressed, the other in a different direction and degree. The first is called the "*ordinary;*" the second the "*extraordinary ray.*" Many crystalline and other bodies possess the same properties, owing to the molecular strain generated in them by the crystalline force. Among these the most remarkable is Iceland Spar, carbonate of lime crystallized in oblique rhombohedric prisms. These crystals have two obtuse and six acute solid angles, a line joining the obtuse angles is called the AXIS of the crystal. In this direction alone it has no double refraction, any plane parallel to this axis is called a "PRINCIPAL SECTION," as A X B Y. In every other it separates the rays in a most complete manner, so that a line seen through a moderate thickness of this substance appears double. We shall return to this property under the head of "polarized light."
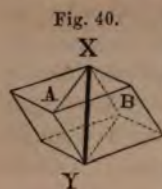
Fig. 40.

Though Iceland Spar alone possesses the property of double refraction in so great a degree as to be at once evident to mere casual observation, a multitude of other bodies have the same power in much lower degree. Thus quartz may be made to show a double image, if formed into a prism, as will be presently explained. So also with glass under pressure; by combining many prisms, a double image may be obtained. Except, indeed, for the mechanical difficulties, similar treatment would develop like results in nearly all crystalline bodies, except those of the "monometric" system, i. e., cubes, octohedrons, and their derivatives, in most animal and

vegetable fibres, shells, scales, granules, etc., and even in some liquids. By certain effects, however, resulting from this double refraction, hereafter to be described, its existence in all these bodies is easily, though indirectly demonstrated. To develop double refraction strongly in quartz, we cut two prisms from a crystal in such a way that in A B C E D the axis of the crystal is in the direction A B, and in B C F G D E parallel to G F, and cement their oblique faces together. A ray then entering the surface A D E I at right angles, suffers no change until it reaches the surface D E C B at X, when

Fig. 41.
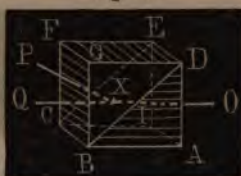
it is separated by double refraction, aided by the obliquity of the prism, into two rays, X P and X Q. This apparatus is called the Prism of Rochon. A similar prism may be made of Iceland Spar, or we may use simply a single prism of that substance, correcting its chromatic aberration, by a compensating prism of glass. Such a "double image prism," as it is called, will give an enormous separation to the two rays, or images.

See APPENDIX, page 294 To show the double image with compressed glass, a system of prisms is arranged, as in the drawing, so that A B C D

Fig. 42.

project and suffer compression from plates of metal forced against their ends. The intermediate prisms, R M N, etc., not pressed, serve to correct in the ray passed from R to T, all deviation, dispersion, etc., except that double refraction produced by the pressure.

Composition of White Light.—We have heretofore spoken of light as if it were all of one kind; a simple motion of a definite sort. Every thing we have said would indeed

be strictly true, say of pure yellow light, such as is pro-
duced by burning alcohol and salt; but would require
certain limitations if applied to white light, which is what
we generally understand by the unlimited noun "light."
This light is far from being simple; and we will now pro-
ceed to study its nature.

Fig. 43.

If a ray of light, passing through
a narrow opening or slit, is al-
lowed to fall upon a refracting
prism whose axis is parallel to
this opening, it will of course be
refracted or bent from its course;
but instead of producing a single
line of light upon a screen placed in its path, it will
develop a broad band, in which all the colors of the
rainbow will be found beautifully blended. It would
thus appear that, in the ray of white light were all these
colors.

This decomposition of white light may be strikingly shown

Fig. 44.

SPECTRA

as follows. (See Fg. 44.) We place as an object, in an ordinary magic-lantern, B, arranged for the lime-light, a plate of brass having an opening in it ⅛ of an inch wide, shaped like a rainbow, with 3 inches span. This being properly "focussed" on a screen, say at a distance of 50 feet, the lantern should be tilted up, as shown in the drawing, and a prism held as indicated by the figure, in front of its object lens. The arch of light will then be depressed by refrac-tion to the proper place on the screen, and broken by dispersion into all the prismatic or rainbow

Fig. 45.

hues. The prism for this experiment should be made by grinding a glass bottle into the shape shown, figure 45, cementing plates of glass on the open sides with the mixture of molasses and glue used by printers to make their "inking-rollers," and filling it with bisulphide of carbon.

We know on general mathematical principles, that the more rapid the vibrations in a ray, the more it ought to be refracted; and we therefore conclude that white light consists of not one only, but many kinds of motions; the slowest of which, separated from the others as at R, is recognized as red light, while the most rapid is seen as violet at V; and all others arrange themselves in gradual progression as indicated in the plate facing page 123.

Nor does our experiment stop here. By the use of deli-cate thermometric apparatus, (see page 121) we find that be-low R, Fig. 43, intense heat is present, gradually fading off as we descend; while a sensitive photographic plate or fluoresent screen will inform us, that above V, (for a distance

5*

more than five times as great as R V, if an electric light and lenses and prisms of quartz are used,) there is spread an influence which, though invisible, acts most powerfully in effecting photo-chemical decomposition, and may even become perceptible to the eye through the influence of fluoresent action, this we call ACTINISM.

The variegated band or ribbon of light thus obtained is called a "SPECTRUM." If sunlight is used in this experiment, and the spectrum, in place of being projected upon a screen, is examined through a telescope into which it is thrown, countless fine black lines will be seen crossing the band, which from their discoverer are called FRAUN-HOFER'S LINES. Passing over their cause, to be hereafter discussed, we at present notice only that they are absolutely fixed with reference to the colors of the spectrum, and their relative places in its length; and being sharp and well defined, are of the greatest use with regard to all purposes of measurement. (See plate.) The most prominent of these are marked upon the plate, and designated by the letters which have always been used to describe them. If by another inverted prism or lens, or otherwise, these colors are united, they produce white light again. It is customary to speak of the colors contained in white light and constituting the spectrum, as seven in number: Red, Orange, Yellow, Green, Blue, Indigo, and Violet; or as 3 primary colors: Red, Yellow, and Blue, with the various tints which would be developed by their combination; as Green composed of Yellow and Blue, Violet of Red and Blue, and Orange of Red and Yellow. In this case, regarding the spectrum as being made of three graduated spectra, one of red, one of yellow, and one of blue light, which, variously overlying each other, produce all the blended tints.

Complementary colors are such a pair as would, united, make white. One of these at least must therefore be a

compound color. Thus, red and green, yellow and violet, blue and orange, are complementary colors. We ought, however, to remember that the above ideas are adopted merely for convenience; and that every tint is as truly a distinct thing, as each note in a musical scale. That each tint of color represents simply so many vibrations per second.

Lengths of Undulations and Numbers per Second.

	Lengths in parts of an inch.	Number in an inch.	Number per second.
Line B.............	.00002708	36.918	451,000,000,000,000
Line C.............	.00002583	38.719	473,000,000,000,000
Middle Red........	.00002441	40.949	500,000,000,000,000
Line D.............	.00002319	43.123	527,000,000,000,000
Middle Orange...	.00002295	43.567	532,000,000,000,000
" Yellow...	.00002172	46.034	562,000,000,000,000
Line E.............	.00002072	48.286	590,000,000,000,000
Middle green.....	.00002016	49.609	606,000,000,000,000
Line F.............	.00001909	52.479	641,000,000,000,000
Middle blue......	.00001870	53.472	653,000,000,000,000
" indigo....	.00001768	56.569	691,000,000,000,000
Line G.............	.00001689	59.205	723,000,000,000,000
Middle violet.....	.00001665	60.044	733,000,000,000,000
Line H.............	.00001547	64.631	789,000,000,000,000

Spectrum Analysis.

We find that certain bodies, when vaporized in a flame, communicate to it definite colors; as sodium, yellow; strontium, red; barium, green, etc.; and we naturally conclude that the particles of these bodies are capable of vibrating at certain rates, corresponding to these colors, and at no others. This supposition is most completely confirmed. If we look at the spectrum produced by a flame otherwise non-luminous (as of alcohol, a Bunsen burner, etc.), in which sodium is introduced, we shall see, in place of the rich band of various colors, simply a single sharply defined yellow line (see plate facing page 123, Na.); showing that

all the vibrations here present, are of exactly one velocity. Strontium, in like conditions giving a purplish red light will show us some red lines and one bright blue (see plate facing 123, Sr. ;) so with other bodies, especially the metals. The amount of the material needed to produce these effects, is extremely small; and we at once see that we have here a most useful and wonderful means of chemical analysis for some bodies.

We provide ourselves with a SPECTROSCOPE, which consists essentially of a narrow slit or opening, a prism, and telescope to examine the spectrum, and a Bunsen burner with a stand supporting a loop of platinum wire. We then fasten the substance to be examined in the platinum wire, support it in the flame of the burner, and examine the spectrum of this flame with the spectroscope. The lines we then see, tell us at once of the presence of certain substances, and the lines we miss, of the absence of others; due allowance being made for certain effects of combination, which we have not here space to discuss.

Absorption Bands

To produce the bright lines above mentioned, the heated body must be in the state of *vapor ;* a highly heated *solid,* gives out rays of all velocities, and hence produces *a continuous spectrum.* But if this mixed or white light—this harmony of various notes — passes through such a vapor, capable of but one or two rates of motion, the rays of the white light which correspond with these, communicate all their motion to the vapor particles, and so lose the power of further onward propagation. Thus, a ray of white light, which has traversed such a vapor, will have lost just those motions which the vapor itself would produce; and if resolved into a spectrum, will show blank spaces, that is in fact *dark lines*, where these rays should have been.

This may be proved experimentally in a most direct and striking manner (see Tyndall, on Heat, p. 427); and furnishes us at once with a means of accounting for the Frauenhofer lines. (This was first pointed out by Bunsen and Kirchhoff). An. de Chem. et Phy. T. 68. p. 5.

The sun's light proceeds from within his atmosphere. This atmosphere consists of incandescent vapors. Each substance in this vapor abstracts certain vibrations, and produces certain blank spaces, or dark lines, in the spectrum. By comparing these dark lines with the bright lines of vaporized bodies, we may determine what materials are found in the solar atmosphere; and thus reach the grand idea of analyzing an orb 95 millions of miles distant. We conclude, in fact, that the principal solar lines indicate, as above, certain bodies in his atmosphere, as follows:

B	indicates	Potassium.
C	"	Hydrogen.
D	"	Sodium.
E	"	Iron.
b	"	Iron and Magnesium.
F	"	Strontium (?), Iron, and Hydrogen.
G	"	Iron.
H	"	Calcium.

We also recognize chromium, nickel, and possibly, zinc, cobalt, and manganese; but find no indications of lithium, copper, or silver.

This process has been also applied to many fixed stars and nebulæ, and has shown us that some of these last (even those which have been resolved; as the dumb-bell, that in sword-handle of Orion, etc.,) are not star clusters, but gaseous bodies; since they give three bright lines, and not continuous spectra. (See Journal of the Franklin Institute, Vol. 49, p. 422).

Vaporized bodies, however, do not alone possess this power of absorption. Many, or all gases, at ordinary

temperatures, liquids, and solids, act in a similar manner;
and the study of these absorption bands has opened a
new field to chemical research. (See Journal of Chemical
Society, 1864, Vol. 2., pp. 59, 304.) Reference will be made
from time to time to these matters, under the heads of
the various substances which have special relation thereto.

Fluorescence. — When light vibrations of very great
rapidity, such as belong to actinism rather than to light,
fall upon certain bodies, they cause them to vibrate, but
with less velocity, so that *visible* rays are thrown off from
them in place of the actinic ones which they have received.
Thus, if the spectrum, made with lenses and prisms of
quartz from the electric light, is caused to fall on a sheet
of paper coated with a solution of sulphate of quinine in
water containing tartaric acid, a long band, above the
part generally luminous, will be seen to glow with pearly
blue light. This light contains dark bands analagous to
the Frauenhofer lines. A great number of substances
possess this power; canary-colored glass, extract of sun-
flower, of horse-chestnut bark, of chlorophyl, of turmeric,
nitrate of uranium, and the natural phosphate of the
same, as also a phosphate prepared in a peculiar manner
to resemble the native phosphate. But none act in so
striking a manner as quinine and canary glass.

Fig. 46.

The light best fitted to develop
these effects, is that obtained by the
electric discharge in a vacuum, and
no experiment in physics can exceed
in beauty that which is seen when
the discharge of a Ruhmkorff coil is
caused to flow from the tinfoil lining
of a canary goblet, over its edge to
the pump plate, under an exhausted
bell-jar. We then have a goblet of lu-

minous emerald, filled with fire, from which pink, purple, and blue streams pour over on every side, and drip at every part.

A very beautiful effect is also produced by passing the discharge through an exhausted electric egg of this same glass, and figures, painted on a screen with quinine, entirely invisible by ordinary light, become luminous in the dark by the light of the "aurora tube" (Fig. 79).

Fig. 47.

Phosphorescence.

When these reverberations or secondary vibrations of light are very persistent, and last for some moments after the cause of them has ceased to act (resembling the *resounding* of a sonorous body, as a bell after it has been struck); we call the phenomenon Phosphorescence, not, however, using this term in the same sense as when it is employed in connection with the body Phosphorus, which, in this sense, is not phosphorescent.

Sulphides of calcium and strontium, exhibit this action in the most prominent manner. Such bodies, exposed to a strong light, and then removed to a dark place, continue to glow visibly for some time. The same effect is also very beautifully shown in some Geissler tubes, which continue to emit light after the discharge in them has ceased.

This is noticed in the form shown at A B, in Fig. 80.

Dispersive Power is the term applied to that property of unequally refracting the different colors, by which the prismatic spectrum, and other similar effects, are produced. This power varies with different bodies, as may be seen from the following table:

Table of Dispersive Powers.

Oil of Cassia	0.139	Turpentine	0.042
Sulphur after Fusion	0.130	Felspar	0.042
Phosphorus	0.128	Balsam Capivi	0.041
Sulphuret of Carbon	0.115	Amber	0.041
Balsam of Tolu	0.103	Calcareous Spar	0.040
Balsam of Peru	0.093	Oil of Rape-seed	0.040
Oil of Bitter Almonds	0.079	Diamond	0.038
Oil of Aniseed	0.077	Olive-oil	0.038
Acetate of Lead, fused	0.069	Gum Mastic	0.038
Guaiacum	0.066	Beryl	0.037
Oil of Cumin	0.064	Æther	0.037
Oil of Tobacco	0.064	Seleinte	0.037
Gum Ammoniac	0.063	Alum	0.036
Oil of Cloves	0.062	Castor-oil	0.036
Oil of Sassafras	0.060	Crown-Glass, Green	0.036
Rosin	0.057	Water	0.035
Oil of Spearmint	0.054	Citric Acid	0.035
Rock Salt	0.053	Glass of Borax	0.034
Caoutchouc	0.052	Crown-Glass	0.033
Flint-Glass, 1st sample	0.052	Plate-Glass	0.032
Oil of Thyme	0.050	Sulphuric Acid	0.031
Oil of Caraway Seeds	0.049	Tartaric Acid	0.030
Oil of Juniper	0.047	Nitre, least refr	0.030
Flint-Glass, 2d sample	0.047	Borax	0.030
Nitric Acid	0.045	Alcohol	0.029
Canada Balsam	0.045	Sulphate of Baryta	0.029
Oil of Rhodium	0.044	Rock Crystal	0.026
Oil of Poppy	0.044	Borax Glass (B.1,Quartz 2)	0.026
Muriatic Acid	0.043	Sulphate of Strontia	0.024
Gum Copal	0.043	Fluor Spar	0.022
Nut Oil	0.043	Cryolite	0.022

Chromatic Aberration.—Its Correction.

From this difference in dispersive power come some important results.

We readily see that our former statements about lenses must be modified with regard to this; namely, that beside other irregularities in the focussing of rays where white light is used, the violet rays would come to a focus much nearer to the lens than the red, and the other colors at various intermediate points; so that from *this* cause we would have an ill defined image fringed with color which would change with the relative position of the screen object and lens. Thus at V the image would have a border of unfocussed red and other rays, and at R of violet and other ones. This would be a most fatal error, but fortunately it may be corrected,

Fig. 48.

thus: A concave lens would of course reverse all the effects of the convex one A, B, and would disperse the colors in an opposite direction. Such a lens, if of equal curvature, would therefore exactly neutralize the dispersion of A, B; but then it would also neutralize the refraction, and thus make the lens as useless as a flat plate of glass. But if the concave lens were made of a substance having a much greater dispersive power than A B, then it would neutralize the dispersion, even though of less curvature, and thus would *diminish*, it is true, but not *destroy* the refractive action of A B. In short, it would make it a lens of longer focus, and "achromatic," that is without color.

The substance commonly used for this purpose is flint-glass. Combining thus a double convex lens of crown-

6

glass, with a plano concave, or with a meniscus lens of

Fig. 49.

flint (there being here two refracting curves for the crown, and one for the flint, see A B), or by uniting two double convex lenses of crown, with one double concave of flint, see C D, we obtain what are called "ACHRO-MATIC," or "CORRECTED LENSES," which are almost free from irregularity of re-fraction. It is, however, impossible to find any two bodies, whose refractive and dispersive powers so exactly correspond as to make an *absolute* correction.

Polarized Light. — We have yet another point to con-sider about the nature of light. Not only is a ray of light composite, in the ways already mentioned, but also

Fig. 50.

as regards the plane in which its vibrations are moving. Thus, a ray of ordinary light may be looked upon as consisting of vari-ous series of undulations, moving in every possible plane containing its line of direc-tion. The cross section of such a ray would be represented by Figure 50, the radial lines indicating the planes in which the particles were vibrating. By various means we may

Fig. 51.

so modify and "sift out" these vibrations, as to obtain a ray in which all are in parallel planes, so that its section would be represented by figure 51, the parallel straight lines representing the planes in which the particles are vibrating.

Plane Polarized Light is that in which all the vibrations are in parallel planes, at right angles to the direction of the ray.

This plane polarized light (the word plane is often
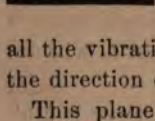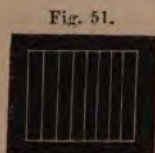
omitted for brevity) may be obtained from ordinary light, in one of the three ways following:

1st. By reflection and transmission. If a ray of light falls upon a transparent reflecting body, such as water or glass, at a certain angle, differing with the substance, it will be partly reflected, and partly transmitted; both parts will be polarized more or less entirely, the one transmitted, in a plane perpendi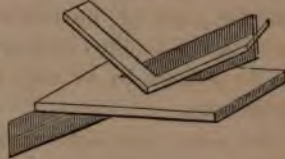cular to the surface of the reflector, and the reflected one at right angles to this. The figure will give a good idea of this action. We here assume only two planes of motion in the ordinary ray, for convenience. In practice, of the other vibrations, those nearest one plane go to it, and those nearest the other to *it*; or escaping, give that mixture of ordinary light to our polarized ray, from which it is never entirely free. The polarizing angle for Glass is 56° 45'; for Water, 52° 45'; for Quartz, 57° 32'; for Diamond, 68°; and for Obsidian, 56° 30'.

Fig. 52.

2nd. By absorption. If a ray of light passes through a slice of the mineral tourmaline, cut perpendicularly to its axis, all its vibrations, except those in one plane are absorbed and destroyed within the crystal, so that the emerging ray is polarized. The iodo-sulphate of quinine in crystals possesses this same property.

3rd. By double refraction. Whenever a ray suffers double refraction, it is also polarized, each of the emergent rays being polarized in a plane at right angles to the other.

Fig. 53.

NICOL'S PRISM (see page 50).

Iceland Spar is the substance used in preparing polarized

light in this way, and since in practice it is desirable to get rid of one of the two rays, the crystal is cut in a plane passing through its obtuse angles, and again cemented together with Canada balsam. By this means the extraordinary ray, A B, suffers total reflection at the surface of the balsam, and is thrown out at the side. This is called a Nicol's Prism. Fig. 53.

Properties of Plane Polarized Light.—These may be most easily understood and remembered by means of a simple physical illustration, which is extremely useful as a means of briefly expressing the facts of the case, though in no respect to be regarded as an explanation of their final cause.

Suppose that light rays are so many flat rulers, and that polarizing bodies are gratings, whose bars are parallel to the planes in which they transmit polarized light. Then an ordinary ray, having its rulers in all positions, coming upon one of these gratings, all the rulers are "reflected," "absorbed," or "refracted, out of the way," except those which are parallel to the bars of the grating, and which therefore get through. If now a second grating is set beyond, parallel to the first, all the rulers which have passed the first will pass it also; but if this second grating is set at right angles to the first, the rulers will all be stopped by the two; for those that passed the first are just those which cannot pass the second.

Thus it is in fact with light. If we place two polarizing bodies in the path of a ray, it will pass, if both are parallel, but will be entirely cut off if they are "crossed." When two polarizing bodies are used, the one nearest the light is called the POLARIZER, and the other the ANALYZER.

Thus Fig. 54 represents an apparatus for developing the effects of polarized light. Light falls upon the mirror A B from the left. The reflected, polarized ray, which is thrown upward, then passes through the tube H H, which

contains an analyzer, such as a bundle of glass plates placed obliquely in the tube. If these last are parallel to the mirror A B, the polarized ray will be reflected, and will not be seen through H H; but by turning this tube H H horizontally through 90° in the socket G G, on which it rests, the light will be no longer reflected, but will be transmitted by the analyzer, and may be seen through H H. A rotation, however, of 90° more, or 180° from the starting point, will again bring the analyzer into a position to reflect all the polarized light from A B and show none of it through H H.

Fig. 54.

Objects to be examined by polarized light, may be placed in the ring F F., and viewed through the analyzer in H H. Plates of doubly refracting substances, display splendid colors, and sections of crystals, the beautiful iris rings to be presently described.

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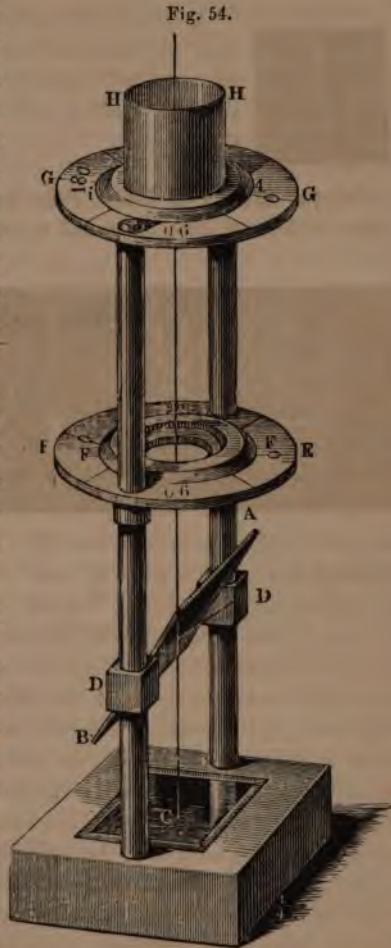
Fig. 55.

A plate of doubly-refracting substance may be regarded as a grating, with two systems of openings (Fig. 55) at right angles, leading off, however, in different directions.

Colored Effects of Plane Polarized Light. — Suppose a ray of ordinary light, A, to fall upon a Nichol's prism, and

Fig. 56.

to yield a plane polarized ray, O. If this ray now passes through a very thin plate of some doubly refracting body, C, placed as represented, the ray will be split into two, p' and s'; one of which will be retarded behind the other, by the distance of part of a vibration (this depending on the nature and thickness of the film); but these, being in different planes, cannot interfere with each other, though they will be so little apart in position as still to be prac- tically together. If now these adjacent yet separate rays fall on another Nichol's prism, each will again be split, and a half of each will be refracted to p' s', while the other halves will be thrown out at p" s". Now p' and s' will be in the same plane, and capable of interfering. If then, white light has been used, and the retardation of one ray behind the other amounts to half a red vibration, the red vibrations in p' and s' will interfere and destroy the red light; if, however, the retardation was half a *red* vibration, it would be more than half a *yellow* or *blue* one;

hence *these* waves would not interfere, and we should have green light at p' s' by the removal of the red. If the plate C were thinner, or of some other material, the retardation would have been less; it then would not have destroyed the red, but some other color, and we should therefore have something else than green at p' s'. If the principal section of the plate C was parallel or perpendicular to the plane of polarization of the light O, it would pass through unchanged, and be transmitted or not by D, according as B and C coincided or not.

If instead of the thin plate C we place a slice, made at right angles to the axis, of a double refracting body, in the same position, with a diverging beam of polarized light, we will have projected on a screen a black or white cross, intersecting a system of consecutive rainbow-colored rings. (See figure 57.) The cause of this may be stated as follows: The slice of crystal may be regarded as having its doubly refracting properties arranged about its centre; or, to give it a physical representation, as having openings for the passage of rays, in radial and circumferential directions, as in the figure 58. Suppose now the polarized light to be vibrating in a vertical plane, its vibrations will pass through in the line M N, and the other radial lines near this, without change; so also through the parts of the circles near X' Y, which are also vertical; and this light

Fig. 57.

Fig. 58.

will then either be stopped or transmitted by the analyzer D, according as that corresponds or is opposite to the polarizer B. This will then give the black or white cross. A vertical polarized ray, striking at R, will, however, find
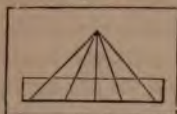
no direct passage, but will be split, part going through the radial, part by the circular passage. These divided rays will be united, and will produce color, as in the case of the thin plate before described. Moreover, the divergent

Fig. 59.

rays, coming on this plate, will have to traverse greater thicknesses the further they come from the centre (see figure 59); thence will produce different colors, and as these differences will vary concentrically about the axis X, the colors will be disposed in rings, intersected by the crosses.

The best specimen for this experiment is a plate of Iceland spar, about one-twentieth of an inch thick, well polished. Such an one, placed as indicated by the drawing

Fig. 60.

Fig. 56, in a good gas microscope, with a screen about 20 feet off, gives a most charming figure, which may be further enhanced by adding to it a plate of quartz, similarly cut and about one-tenth of an inch thick.

Some bodies, such as nitre, have two axes of no double refraction near together. Similar slices from these give double systems of rings, crossed by dark or light "brushes," produced by union of two crosses. (See

Fig. 61.

Fig. 60). Other crystals of two axes, such as sugar, aragonite, etc., have these so far apart that only one system of rings and brush can be seen at a time. (See Fig. 61.)

These actions of polarized light are used in a variety of ways in chemical investigations. The change of color produced by polarized light in many bodies, crystalline and organic, help us to recognize them; and

the presence of these crosses or colored rings are similarly useful, besides helping us to study the condition of crystalline bodies, in relation to their condition of mechanical strain.

Blocks of glass, gelatin, etc., strained by pressure or sudden heating or cooling, exhibit colored figures, having

Fig. 62.

remarkable analogy to those of crystals. These, when used in the gas microscope, must have an object-glass in front of them, between them and the analyzer.

Rotation of the Polarized Ray.—If in place of the slice of Iceland spar, in the experiment just described, we put a similar plate of quartz, cut from a crystal at right angles to its axis, we shall have a system of colored rings as before, but instead of the cross, black or white, the central space will be filled with colored light, which will change, as the analyzer D is rotated, through all the colors of the spectrum. The reason of this is as follows: This substance, though like others it does not produce double refraction along its axis, etc., *does* twist the plane of the polarized ray, giving its edge, as we may say, the shape of a screw-thread. The amount of this twist is, however, different for each color. Hence in each position of the

analyzer some colored rays will pass, while others will be stopped; thus the colors are produced.

Some specimens twist the ray in one direction, others in the opposite. Those which so turn it that the colors change upward, from red through yellow, green, etc. to violet, when the analyzer is rotated over the crystal in the direction that watch-hands move over its face, are said to have right-hand polarization, or to be dextrogyre; those that change oppositely from violet, through green, etc., to red, by the same motion, or similarly to the first by an opposite motion, are said to have left-hand rotation, or to be lævogyre.

The amount of this polar rotation varies with different bodies, and in the same body with its thickness.

This power of rotation belongs to other solid bodies besides quartz; to others, as Faraday's heavy glass, it may be communicated by magnetic action; and it also exists in some liquids and solutions, as that of cane and grape sugar.

Saccharimeter.—With regard to these substances this property is used as a commercial test of value. By means of an appropriate apparatus, a given depth of solution, containing a known quantity of the sample in question, is examined by polarized light, and the amount of rotation suffered by a given color being ascertained, we may from this estimate the quantity of the corresponding substance contained in the solution. Cane sugar has right, and grape sugar left-hand rotation. If these are mixed they in part neutralize each other's effect; we must, then, after our first determination, convert the whole into grape sugar by hydrochloric acid, and then, having made a new determination, settle by a subtraction the original proportion of each. This process may be applied to many other substances.

Circularly Polarized Light is that in which the vibrations are in two planes, at right angles to each other, but differing also in phase by an odd number of quarter-wave lengths. It may be produced by passing a ray of plane polarized light, through a Fresnel's rhomb (Fig. 63), when suffering two total reflections at an angle of about 54°, it will issue with the properties required for circular polarization. Circularly polarized light may

Fig. 63.

also be obtained by Airy's method, if ordinary light is made to fall vertically on a film of mica or selenite, of such a thickness, that the ordinary ray shall be retarded more than the extraordinary by the required amount.

With circularly polarized light the images produced by slices of crystals are changed, the black cross disappearing, and the alternate segments of the rings being dislocated. Thus, for Iceland spar, we have the Figure 64.

Fig. 64.

Elliptically Polarized Light is that in which the vibrations are in two planes, perpendicular to each other, but differing by some quantity, not an exact multiple of quarter-wave lengths. This is obtained from a Fresnel's rhomb if the incident and refracted rays have any other angle than 45° between their planes; also if common light is reflected from a metallic surface.

ELECTRICITY.

We indicate by this term the cause of a certain class of phenomena, such as the attraction which amber, etc., possesses for light bodies after being rubbed, the lightning flash, the decomposition of bodies by a galvanic apparatus, the polar position of a magnet, etc.

Theory of the Double Fluid. — In giving a physical explanation of electric phenomena, and connecting them in a way convenient for study and reference, we must begin by making certain assumptions, which, however, it must be remembered, have no other proof than that they serve to connect and explain the phenomena in question.

We assume that all space and all matter is pervaded by two impalpable fluids, alike in general character, but having, in certain respects, exactly opposite properties; that, for this reason, when mingled in equivalent quantities, they entirely neutralize each other, as regards these opposing properties, and show no signs of their existence (these fluids, together or separately, may perhaps constitute that æther, to which we have before alluded, as serving to transfer the vibratory motions, which we recognize as light and heat). These opposite electric fluids we designate as positive (+), and negative (—), and their assumed properties may be very briefly stated.

The particles of each fluid are mutually repellant, but attract those of the opposite fluid, and of matter generally. They are capable of rapid motion or transfer through some bodies, as metals, moist air, etc., but are almost precluded from traversing others, as glass, shellac, dry air, etc. They may be, 1st, separated and confined in or upon certain bodies; or, 2nd, set in rapid motion in opposite directions; or, 3rd, caused to form series of currents in the individual particles of certain substances. These three conditions give rise to three divisions of our subject, Statical Electricity, Galvanism, and Magnetism.

STATICAL ELECTRICITY.

By this term we indicate that condition of the electric fluids in which they are separated more or less completely, and confined for a greater or less time, to certain bodies.

The methods by which this separation may be effected

are numerous, but the simplest and most characteristic is by *friction*.

If two different substances are rubbed upon each other, their electric fluids will be more or less separated; an excess of the positive fluid collecting in one, and of the negative in the other. Experiment: Rub a glass rod with a silk handkerchief; bring the rod near a pith-ball suspended by a silk thread, the ball will be attracted; so also will it be by the silk (each fluid in turn attracts the matter of the ball). Now touch the ball with the rod, then ball and rod will have the same fluid; hence the ball will now be re-pelled by the rod, but will be more powerfully attracted by the silk than before (these two have now opposite fluids which attract). In this case the glass collects the positive fluid, the silk the negative.

The power of collecting one or the other fluid is not positive in certain substances, but simply relative; the body which takes positive and loses negative fluid by friction with one substance, will, with another, take negative and yield positive. Arranging all substances in their order of positive or negative attraction we would have a table like the following, in which any substance, rubbed with one below it, will take positive fluid, but rubbed with any above it will take negative fluid. This is what we mean by calling a body ELECTRICALLY POSITIVE or NEGATIVE. The bodies at the beginning are, in a general sense, posi-tive; those at the end negative; but any substance is positive to any one below it, and negative to any one above.

Table of some Substances in their Electrical Relations.

Fur.	Paper.
Smooth glass.	Silk.
Woollen cloth.	Lac.
Feathers.	Rough glass.
Wood.	Sulphur.
	Gun-cotton and like bodies.

Conductors and Insulators.

Bodies through which the fluids easily pass are called Conductors, those which resist their motion, Non-conductors or Insulators. These properties are relative, as we may see by the following table, which begins with the best conductors, and ends with the worst, which is, therefore, the best insulator.

In the following list the bodies are arranged in their order of conducting power, according to the present state of knowledge on the subject, and though probably not absolutely correct, it will serve to show how insensibly conductors and non-conductors merge into each other: —

Table showing the Relative Conducting Power of Certain Substances for Electricity.

Metal, *best conductor*.
Well-burnt charcoal.
Plumbago.
Concentrated acids.
Powdered charcoal.
Dilute acids.
Saline solutions.
Metallic ores.
Animal fluids.
Sea water.
Spring water.
Rain water.
Ice above 13° Fahr.
Snow.
Living vegetables.
Living animals.
Flame smoke.
Steam.
Salts, soluble in water.
Rarefied air.
Vapor of alcohol.
Vapor of ether.
Moist earth and stones.

Powdered glass.
Flowers of sulphur.
Dry metallic oxides.
Oils, the heaviest the best.
Ashes of vegetable bodies.
Ashes of animal bodies.
Many transparent crystals, dry
Ice below 13° Fahr.
Phosphorus.
Lime.
Dry chalk.
Native carbonate of bary·es.
Lycopodium.
Caoutchouc.
Camphor.
Some siliceous and argillaceous
stones.
Dry marble.
Porcelain.
Dry vegetable bodies
Baked wood.
Dry gases and air.
Leather.

Parchment.	Mica.
Dry paper.	All vitrifications.
Feathers.	Glass.
Hair.	Jet.
Wool.	Wax.
Dyed silk.	Sulphur.
Bleached silk.	Resins.
Raw silk.	Amber.
Transparent gems.	Shellac.
Diamond.	Gutta percha, *worst conductor.*

The Electrical Machine.

To effect this separation of the fluids with ease, we employ an "electrical machine," which consists of a glass disk, A, mounted on an axle, and turned by a handle, of a "*rubber*," B, made of leather spread, with mosaic gold (bisulphide of tin), and supported on a glass column; of a silk apron, E, of collecting points, F, and of a round ended cylinder of metal, G, called the "*prime conductor*," supported on a glass column. The positive electricity, developed in the glass, by friction on the rubber, when the former is turned, is car-

Fig. 65.
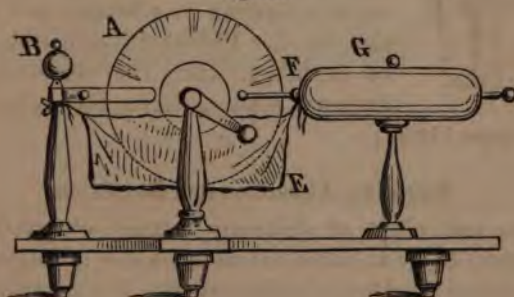
ried round to the points, being protected from escape by the apron. At the points it is drawn off into the

prime conductor, where it collects. The negative electricity accumulates in the rubber. To get much positive electricity, we must connect the rubber with the earth, by some good conductor; to get much negative, we must in like manner connect the prime conductor, insulating of course the rubber.

With this apparatus, many ingenious experiments, illustrating the attractive and repulsive powers of unlike and like fluids, may be performed, such as the dancing images, the sportsman and birds, the dancing pith balls, the industrious spider, the electric flyer, and orrery, etc.

Hydro-Electric Machine.

A similar separation of the electric fluids may be effected by the friction of steam, containing particles of water in suspension, on the sides of peculiarly shaped orifices. (See Fig. 66.) In this case the orifices become negative, the issuing steam positive. Points placed opposite the escaping steam will collect the positive fluid. Again, by the dry pile to be described hereafter, see page 101, this same separation is effected; and again, also, by the Ruhmkorff coil, which will be described, when the necessary preliminary matters have been discussed. (See page 117.)

Fig. 66.
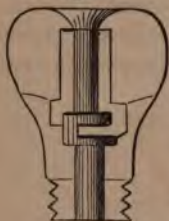
Electrical Attraction and Repulsion.

The first effect of electricity actually observed, and that most likely to excite attention, is the attraction and subsequent repulsion of light bodies. The connection of these actions with our theory of electricity has been already explained, page 72, but the phenomena themselves may be strikingly exhibited by the following pieces

of apparatus and instruments for measurement of electric force :

The chime of bells (Fig. 67) consists of a brass rod,

Fig. 67.
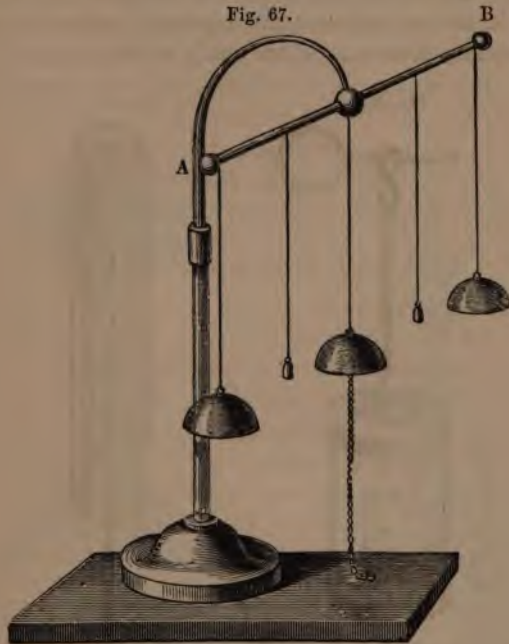
A B, supported by a stand, and connected by a chain or wire with an electrical machine. From each end of this rod hangs by a chain a metallic bell, which thus receives electricity from the machine. Near each bell hangs by a *silk* thread a little brass ball or clapper, which is attracted by the bell, until it strikes it, when, receiving a charge of fluid, it is repelled in turn, but attracted then by a centre bell which is suspended by a silk cord from the rod, A B, and is connected with the ground by a chain. Each clapper, as it strikes this bell, therefore gives up its elec-

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tricity, and is then again attracted to the outer bell, so
that a constant motion and chiming is thus maintained.

The dancing pith-balls (Fig. 68) exhibit a like action.
The balls are in this case first attracted by the upper plate,
touch it, become charged, are repelled ; strike the lower
plate, so lose their charge, are again attracted, and so on.

Fig. 68.   Fig. 69.

The electrical umbrella (Fig. 69) consists of many strips
of colored paper connected with a brass rod, which may
be supported on the prime conductor of an electrical ma-
chine.   These strips, being all similarly excited, repel each
other, and so stand out like an open umbrella, when the
machine is in operation.

On a similar principle is constructed the quadrant elec-
troscope.   In this the brass rod fits into the prime con-
ductor, and has attached to it a light rod with a pith-ball.
This being charged similarly to the rod, is repelled from it,

the amount of its repulsion, measured on a small quadrant, indicating the intensity of the charge.

This is, of course, but a rough instrument; one far more delicate is furnished in the gold-leaf electroscope, Fig. 70. Here two strips of gold-leaf (Dutch gold is best) are suspended from a brass plate, in a glass vessel; any electric fluid passed into them causes them to repel each other, and so diverge.

Fig. 70.　　　　　　　　　　　Fig. 71.
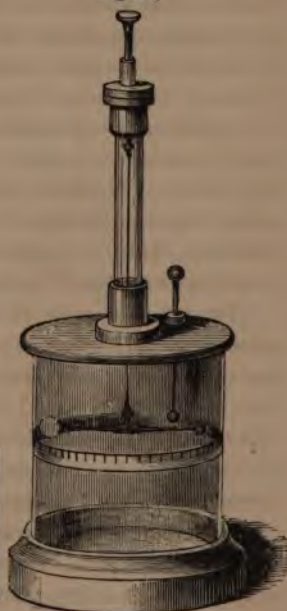
A more delicate instrument, of like nature, is seen in Coulomb's electrometer, Fig. 71. In this case a light rod of gum shellac carries at one end a pith-ball, and is supported by a fibre of silk, the whole being inclosed in a glass vessel; a small brass ball terminates a wire which enters

this vessel. If this wire, and consequently the brass ball
is excited, it first attracts the pith-ball, but then, after con-
tact, repels it, so twisting the silk fibre. The distance to
which the pith-ball is repelled in this, as in a former case,
indicating the intensity of the electrical excitement in
question.

Distribution of Electricity.

The electric fluids, when separated as above, always
reside on the surfaces of bodies. Thus, in non-conductors,
they cannot penetrate the substance, and being collected
at the surfaces must remain there; and in conductors, by
reason of the mutual repulsion of like particles, they are
forced outward to the surface. Opposite fluids, put in the
same conductor, would, of course, mingle and neutralize
each other. By reason of this repulsion, the fluids readily
collect on and escape from projections and points; and
similarly enter a conductor by such points from a sur-
rounding surcharged medium.

Thus we terminate all instruments, intended to retain
electricity, with rounded surfaces, balls, and the like; but
use points where we desire to introduce the fluids, as in
the collecting points, F, Fig. 65, of the electrical machine
(these points are attached to the brass rods, one of which
is shown in the drawing, along their inner sides, and are
directed towards the glass plate).

So, again, with LIGHTNING RODS; these should have
sharp points, for, if thus provided, and in *good connection
with the ground*, they attract and gradually withdraw from
the approaching thunder-clouds their charges of electricity,
and thus often *prevent a " flash*," as well as divert to a
safe channel those not to be so obviated.

That electricity occupies alone the outer surfaces of
bodies, may again be shown if we provide a hollow metallic
sphere, with an insulating support and an opening by

which its interior surface may be reached. Then, when the sphere has been charged, electricity may easily be obtained from its outer surface by touching it with a "test-plane," i. e. a little button or wafer of brass mounted on a glass handle; while none can be obtained by this means from the inner surface. The "test-plane," after touching the sphere, should be brought in contact with the plate of the electroscope, Fig. 70, when the gold-leaves will diverge, if any electricity has been received by the planes.

Induction of Electricity. — This phenomenon, like the last, is the direct, necessary consequence of those general properties of the electric fluids, stated at the commencement of this subject.

Thus, suppose a conductor charged with positive electricity, to approach an insulated conductor in the natural state, without touching it. Then the positive fluid in the charged conductor will drive the positive fluid in the insulated conductor to its further side, and draw the negative fluid to the nearer. The fluids would in this way be separated in this insulated conductor, so long as the charged one remained near it. This mode of separating the fluids we call "induction." It develops some curious consequences.

The Electrophorus. — Suppose we have a shallow pan, filled with solid shellac, and excite this negatively by friction; that we then place upon it a plate of brass, varnished with shellac, and having a glass handle. The lower face of this will become positive, and the upper negative, for the reasons just stated. If now we connect this with the ground for a moment, by touching it with the finger, the repelled negative fluid will escape, and some positive will enter to fill

Fig. 72.

the space of that drawn towards the shellac. If this plate is now lifted away from the shellac, by its glass handle, it will clearly have in it an excess of positive fluid, which, being no longer held to one place by an attraction, can pass all over it and escape. This action can be repeated without loss of electricity to the shellac, and thus furnishes a supply of that agent, which admits of many ingenious applications, among others the lighting of gas burners, as in the many forms of apparatus for that purpose, invented by Robert Cornelius, Esq., of Philadelphia.

The Leyden Jar. — We have already noticed, that the electric fluids, by reason of repulsion, reside on the surfaces of conductors, and tend to escape therefrom. Such bodies are thus unfit to serve as reservoirs of this agent, but by an application of this fertile action of "induction," the difficulty is surmounted.

We coat a glass jar inside and out, nearly to the top, with tinfoil. We close the mouth with a cork or cover of wood, through which passes a rod, connected metallically with the inner coating. Holding the jar by its outer coating in the hand, or otherwise connecting it with the ground, we then pass electricity into the inner coating, by the rod. As this spreads over the inner coating, it drives away a corresponding amount of the same fluid from the outer coating, and draws into it an equiva-

Fig. 73.

lent amount of the opposite, so that the two coatings become oppositely charged, and these fluids, attracting each other, do not tend to escape. This apparatus is called the Leyden Jar.

A number of these having their outer coatings united by strips of tinfoil pasted in a box which contains them, and their inner coatings united by brass rods, form a "battery of Leyden Jars." To use the electricity thus stored, we make such a connection

that it may pass from one to the other coating, through
the object or apparatus we wish
it to traverse.

Fig. 74.

Transfer of Electricity.— Elec-
tricity may pass from one body
to another, by three different
methods; by conduction, by con-
vection, and by discharge.

Conduction is the transfer
through particles in contact. This
takes place with different facility, in different bodies, as
has been already mentioned, see page 74, and also varies
with the temperature of the same body, diminishing with
an increase of heat. Where the size of the conductor is
sufficient for the quantity of the current to be conveyed,
no change is produced; but when the conductor is insuf-
ficient, and resists the passage of the fluid, heat is
developed. Thus a large battery being discharged through
a strip of gold-leaf, placed between two plates of glass,
melts and vaporizes the gold; driving it into the glass,
so as to produce a purplish stain. So with a fine wire
of iron, or platinum, etc.

When passing freely through a good conductor, elec-
tricity moves with a velocity of 288,000 miles per second.
This was measured by Wheatstone, in 1834. (See Philo-
sophical Transactions for that year, page 589.)

Convection is the transfer of electricity by motion in
particles of an interposed fluid, such
as air. Thus, the air particles touch-
ing a charged conductor, get the same
fluid, and are repelled, move off to
some neutral or oppositely charged
body, and allow others to take their
place. These in turn follow the same
course, a current is established, and

Fig. 75.

the electricity is thus transferred. This may be well shown by attaching a pointed wire to the prime-conductor of a machine, and holding a burning candle or lamp near it. The flame will then be blown aside, if not extinguished, by the draft of air.

Discharge is the simultaneous transfer of electricity developed by induction in the particles of an interposed non-conductor. Thus, particles A B C etc., in a given line, being excited by mutual induction, make a discharge when A gives its fluid to B, at the same time that B gives its own to C, and so on. This transfer may be more or less resisted, and its character thus modified, by the interposed substance. We accordingly have two classes of discharge, the *disruptive discharge*, flash, or spark, where the fluids pass through a highly resisting medium, and the *diffused* or *flame discharge*, where the medium offers but slight resistance. Between these there may be every possible gradation; but we may include all cases in one or other of these classes, without further division.

The Disruptive Discharge is seen when the fluids pass through the air, as in the ordinary spark from the machine, from the Leyden jar, from the induction coil, and in the lightning. In all cases it is accompanied by a light and sound, both varying in intensity with the amount of electricity which is passing. The color of the light varies with the points between which, and the medium through which, it passes. In all our experiments the spark is accompanied by a transfer of the material of which the points are made, and it is only reasonable to conclude that the light owes its existence to the vibrations produced in these particles, as they are torn off from one point and thrown towards the other.

The sound is caused by the rapid heating and cooling of the air in the path of the flash, thus producing in it such a vibration as will affect our ears.

Viewed through the spectroscope, the light of this discharge gives only *bright lines*, varying with the substances, showing that they are in a gaseous state when developing this light. (Pro. of Roy. Inst., 1863, p. 47.)

Many pretty experiments may be made with this discharge — as the lightning-jar, the lightning-plate, the spark-plate, the letter-plate, the luminous profile, the lightning-house, etc.

This spark is capable of igniting many compounds,— as gun-cotton, ether, explosive mixture, burning gas, etc.; but will not fire gunpowder, unless it is retarded, as by passing through a wet string.* It will also effect many chemical changes of combination and decomposition. For igniting most of these bodies we place them upon the table of the universal discharger, Fig. 76, and then pass

Fig. 76.
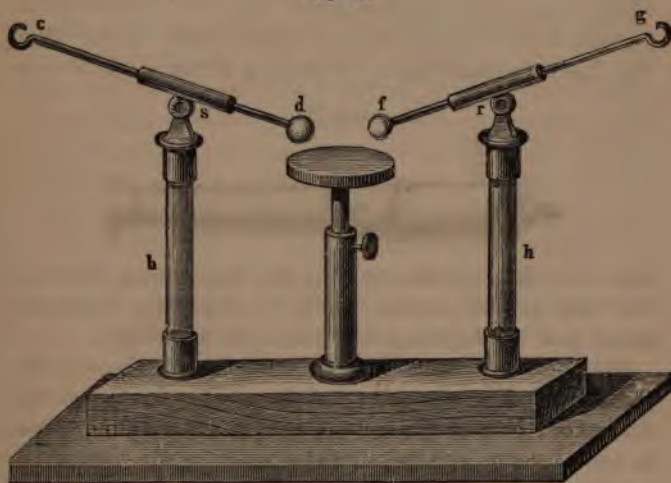
* In this experiment the wet string must be between the powder and the *negative* coating

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the spark through by means of the adjustable rods c d f g, supported on the glass columns h b.

Liquids like ether we place in a spoon, and take a spark into it by a wire hung from the prime conductor of a ma-

Fig. 77.

chine; and for explosive gases, such as a mixture of oxygen and hydrogen, we use a little brass cannon (Fig. 78), having a small brass rod passing through a glass tube

Fig. 78.

into it, so that a spark entering this may spring across to the body of the cannon inside, so firing the contained gases, and driving out a cork placed in the muzzle.

If an egg be placed upon the table of the universal discharger, Fig. 76, and the spark from a Leyden jar, or the Ruhmkorff coil, be passed through, it will be illuminated in a remarkable manner, so as to have the appearance of being *red-hot*.

Its vitality is of course destroyed, but it is otherwise uninjured by this treatment.

The Glow Discharge.—This takes place when the interposed medium offers little resistance to the passage of the fluids. This is well seen where the discharge traverses rarefied air, gas, or vapor, as in the aurora tube (Fig. 79), where the tall glass tube is exhausted by the air-pump, and then has its caps connected with the poles of a Ruhmkorff coil.

Fig. 79.

The color of the discharge in this case is chiefly effected by the rarity and nature of the interposed medium. This is well illustrated in the Geissler tubes (Figs. 80 and 81), which are filled with various gases, and then exhausted, by means of a mercurial air-pump, to a Torricellian vacuum, or nearly so, and sealed. If now the platinum wires, passing through their ends, are connected with the poles of a Ruhmkorff coil, streams of beautifully variegated light will fill them, crossed by obscure bands. With hydrogen this light is chiefly pale purple; with nitrogen pink, with a violet-blue glow, filling the negative end of the tube, where the wire, entering the bulb, will be coated as it were with a layer of orange-colored light. Bulbs of Canary glass placed within these tubes, as in C D, Fig. 80,

Fig. 80.
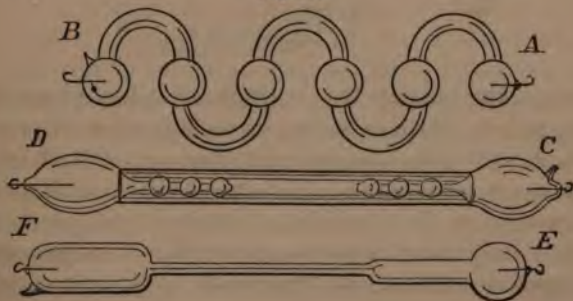
glow like so many emeralds amid the purplish and pink light of the discharge. In some cases the exhausted tubes, bent into complex forms, are surrounded by other tubes, which may be filled with various fluorescent or even simply colored solutions. Thus in Fig. 81 we fill A C with a solution of quinine and B D with nitrate of uranium. We then have the negative ball, say F, full

Fig. 81
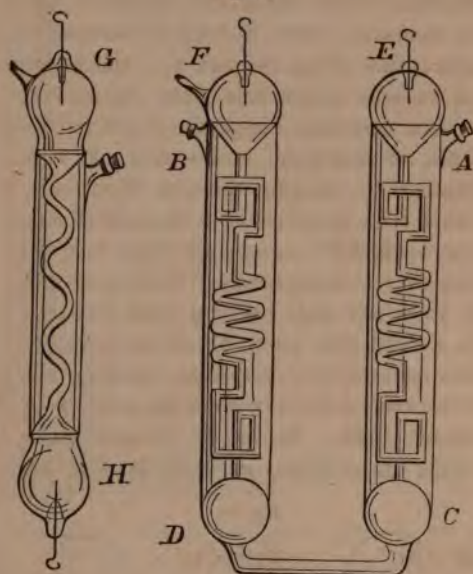
of blue light, the part D C brilliant rose-color, F purplish-pink, and the portions within the solutions are bordered from A to C with a magnificent blue, and from B to D with a rich green color. The single tube G H (Fig. 81) is arranged on the same plan. Simple colored solutions, such as bichromate of potash and sulphate of copper, may be used in place of the fluorescent ones, with equally

beautiful effect. There are few things, if any, within the range of philosophical experiments to be compared for beauty with these just described.

If a double barometer (Fig. 82) has its two mercury columns connected with the poles of a "coil," a stream of light will pass through the arched vacuum above. This light will be white, on account of the vapor of mercury present. AN ABSOLUTE VACUUM (obtained by placing caustic potash in a vessel filled with carbonic acid and then exhausted, and allowing the potash to absorb the last trace of this gas) is totally impervious to the electric discharge. If, however, the potash is heated the discharge will be renewed, the slight vapor produced seeming to furnish matter sufficient for this action. This same effect was observed with the intense water-battery of 3520 cells used by Gassiot as well as with the coil. (Philosophical Transactions, 1859, p. 148.

Fig. 82.

MAGNETISM.

Magnetism is that department of electricity which treats of the properties of magnets.

A magnet is a body which has the power of attracting iron and some other metals, and of setting itself in a definite position with reference to the earth's axis, so that one end points *toward* the north pole.

According to our theory, a magnet owes these, and its other peculiar properties, to the fact that the electric fluids

8*

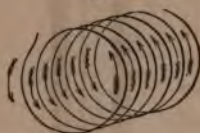in its various particles are not at rest, but are flowing in opposite directions, making a series of closed circuits in each particle. Regarding for simplicity the positive fluid alone, Fig. 83 would indicate the condition of a magnet. The small spheres representing particles, and the arrows showing the directions of the currents of positive fluid in each. The negative fluid we suppose to be forming similar currents in the opposite direction. With the direction for the positive current indicated in the figure, the front end (to the right) would be the South, the other end the North pole. These directions being reversed, the poles would be reversed also. The aggregate effect of all these currents would evidently be nearly identical with a close spiral around the surface, as in Fig. 84.

Fig. 83.

Fig. 84.

Of magnets, we have — natural magnets or loadstones, artificial magnets, and electro-magnets. The end of any magnet, which turns towards the north, we call its north pole, the other the south pole.

Loadstone. — This is a peculiar ore of iron, being a mixture of the proto and sesquioxide of iron ($FeO + Fe_2O_3$), found abundantly in nature, and possessed of the magnetic properties already mentioned.

Artificial Magnet. — This is a bar or rod of steel, which has received magnetic properties by being rubbed with another magnet, or placed within a spiral galvanic current. Such a magnet will possess all the peculiar properties of the natural loadstone, generally in intenser degree.

These magnets are sometimes made in the shape of straight bars, sometimes they are bent into the shape of a

horse-shoe or of the letter U. These are called " HORSE-
SHOE or U MAGNETS." They gradually lose their mag-
netic properties unless a bar of soft iron is kept across their
poles as S N, Fig. 85. This bit of iron is called an " ARM-
ATURE." A magnetic bar made light, and delicately

Fig. 85.
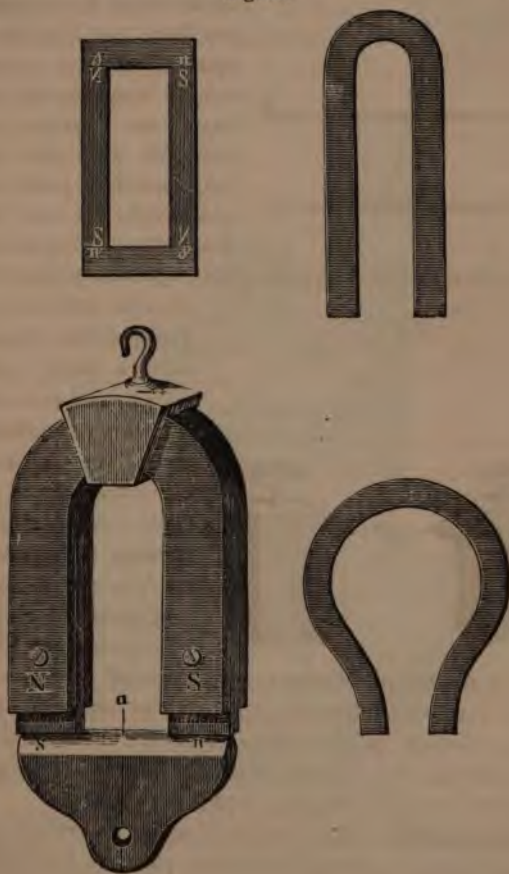
balanced, so as to turn horizontally about a point, is called "*a magnetic needle.*"

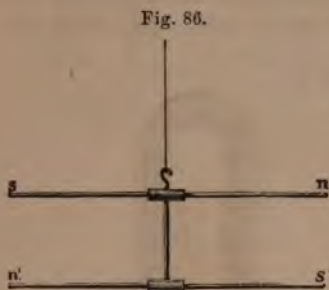Two such needles, fastened one over the other with reversed poles, form an *astatic needle*, which will stand east and west, and be deflected by a very feeble force, see Fig. 86. In practice astatic systems are so constructed as to have one needle more powerful than the other; they therefore point north and south, but can be deflected by very feeble forces.

Fig. 86.

With all magnets, like poles repel, opposite poles attract.

Besides iron, in its various forms, magnets attract feebly nickel, cobalt, and chromium; and very powerful magnets have also a peculiar effect on all other bodies, causing some to arrange themselves in the line of their poles, and others at right angles to this, see Fig. 87.

Fig. 87.
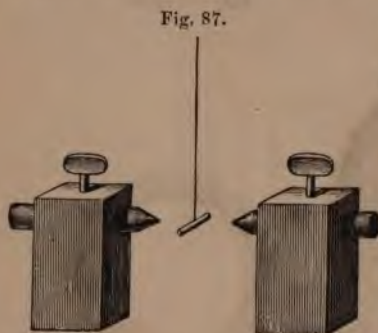
The first are called MAGNETIC, the second DIAMAGNETIC bodies. Among the magnetic substances are salts of iron, even in solution, as also those of chromium and manganese; among the diamagnetic are bismuth, antimony, phosphorus, most gases, and organic bodies.

Electro-magnet.—This is a bar of soft iron, around which a spiral galvanic current is made to pass, as, for example,

in a bobbin of insulated wire. Such a body has all the properties of a magnet so long as the current continues, but loses them the moment this current ceases.

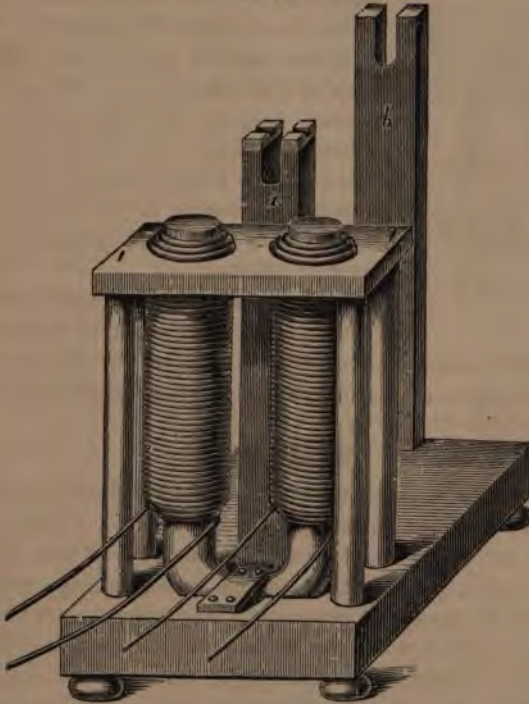In electro-magnets the wire is generally wound entirely *outside* of the iron bar; so that the current produces its

Fig. 88.

Fig. 89.

effect only inwards. A very ingenious modification has been made, however, by Mr. Eben Jayne, in which the

Fig. 90.

whole influence of the current is utilized. In
this, the coil is wound on a bar of iron which
forms one pole, while a cylinder of iron, slipped
over the coil and joined to the bar at one end by
an iron cap forms the other. See Fig. 90.

Magnetism by Induction. — Whenever a magnet is
brought near a bar of iron or steel, it con-

Fig. 91.

fers upon it, all magnetic properties. The
poles of the induced magnet are opposite
to those of the inducing one. Thus, if the
horse-shoe magnet, N S, have two iron
keys brought near it, as in the drawing,
the keys will be magnetized by induction,
with poles, as shown in the figure; and
nails, in turn brought near to these, would
be likewise affected.
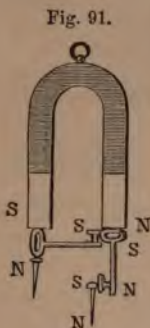
If the body once magnetized in this or
any other way is of steel, it retains its
magnetic properties, but if it is of wrought iron, it loses
them, as soon as the magnetizing agency is withdrawn.

GALVANISM.

Galvanism is that department of electrical science which
treats of the phenomena first pointed out by Galvani and
Volta, as the result of certain connections of two metals
and a liquid, and of other actions having a close relation
to these in cause and character. According to our theory,
we believe that when two metals are immersed in a liquid
capable of acting chemically upon one of them, and are
connected by a good conductor, as the chemical decompo-
sition of the liquid, which ensues, progresses, the electric
fluids are separated, and caused to pass in opposite currents

through the circuit of the materials employed; the positive fluid, going to the metal least acted upon, thence through the conductor to the other metal, and so through the liquid to the starting-point again; the negative fluid following, meanwhile, the same path in the opposite direction.

Fig. 92.

Such a combination of parts is called a galvanic "COUPLE;" many of these connected form a "BATTERY;" couples of certain forms are called "CELLS." The two metals or their equivalents (for non-metallic bodies may in some cases be used) are called "ELEMENTS;" the one most acted upon being always the positive substance (see page 73); the other the negative. The positive fluid will, however, always come *out* from the negative element. The fluid used is commonly called the "EXCITING LIQUID."

In the following table each substance is negative with all above, and positive with all below it, when placed in galvanic relation. This order is in some cases, however, effected by the nature of the fluid employed. See Phil. Transactions, 1840, p. 113. Diluted sulphuric acid is the exciting liquid assumed in the table here given:—

Electro-chemical Order of the Principal Elements.
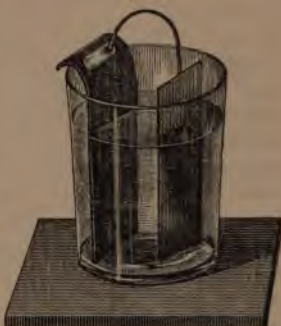
Electro-negative.	
Oxygen.	Iodine.
Sulphur.	Phosphorus.
Selenium	Arsenicum.
Nitrogen.	Chromium.
Fluorine.	Vanadium.
Chlorine.	Molybdenum.
Bromine.	Tungsten.
	Boron.

Carbon.	Cobalt.
Antimony.	Nickel.
Tellurium.	Iron.
Titanium.	Zinc.
Silicon.	Manganese.
Hydrogen.	Uranium.
Gold.	Aluminum.
Platinum.	Magnesium.
Palladium.	Calcium.
Mercury.	Strontium.
Silver.	Barium.
Copper.	Lithium.
Bismuth.	Sodium.
Tin.	Potassium.
Lead.	**Electro-positive.**
Cadmium.	

The terminal points of the series, where the connection outside of the liquid is not completed, are called the positive and negative " POLES " or " ELECTRODES," according as the positive or negative fluid comes from them.

Galvanic Batteries.

Omitting those forms of galvanic batteries which, however interesting in an historical connection, are not practically useful, and have therefore been abandoned, we will describe the forms now generally employed.

Hare's Calorimeter.

This consists of two very large spirals of sheet zinc and copper, wound together, in close proximity, without contact. This is accomplished by interposing strips of cardboard while hammering into shape, these being afterwards removed, and the strips sustained and kept in place by wooden bars, as indicated in the Figures 93, 94, 95. This pair of plates is then immersed in a tub, bucket, or large jar of diluted acid, and for a short time will act with wonderful energy. The hydrogen, liberated by the decomposition of the water (whose oxygen goes to the zinc form-

Fig. 93.
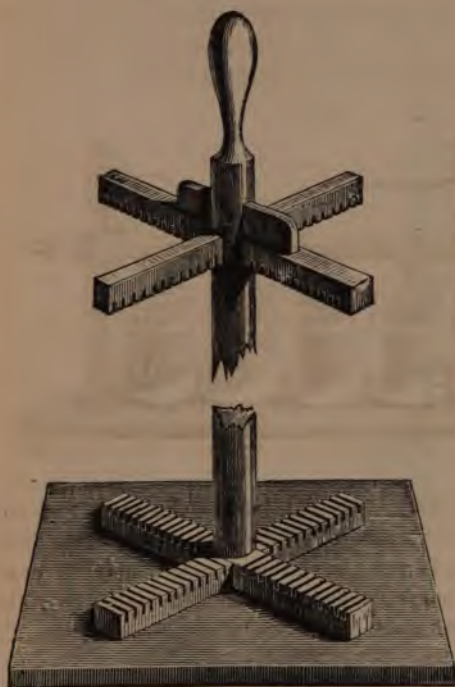
Fig. 94.

Fig. 95.

ing oxide of zinc, which is then taken up by the acid), at once attaches itself to the copper-plate in countless bubbles, which not only interfere with the con-ducting power of the series, but present a *positive* surface in place of the *negative* copper, thus causing the battery rapidly to "run down," or lose strength.

Smee's Battery.—In this each cell consists of a glass jar, containing diluted sulphuric acid, in which hang from a cross-bar of wood three plates, the middle one of pla-tinum, coated with a deposit of the same metal finely

9

divided, to which hydrogen bubbles will not adhere.   At
each side of this hangs an amalgamated zinc plate.
These two zinc elements are united, so that they act as
one.   In connecting several of these, the zincs of one cup

Fig. 96.

are joined by a wire to the platinum of the next, and so
on.   In place of platinum plates leaden ones, coated first
with silver, and then with platinum black, may be em-
ployed.   This battery is feeble but steady, and may be
charged and left for a long time without deterioration, if
the connection is not made between its poles.

Daniel's Battery.—In this each cell consists of a copper
vessel, containing a solution of sulphate of copper; within
this a porous cell or cup of unglazed earthenware, con-
taining diluted sulphuric acid, in which is immersed a
cylinder of zinc.   The hydrogen liberated in this case
passes into the sulphate of copper, decomposing it and
throwing down metallic copper, by combining with the
oxygen of the oxide of copper in the salt, so forming
water.   This battery, therefore, gives off no gas at all,
and (some crystals of sulphate of copper being placed on
a shelf in the outer vessel to restore the solution as it be-
comes impoverished) is very constant.   It is, however,
feeble, as compared with the following forms.

Grove's Battery.—In this each cell consists of an outer jar, containing diluted sulphuric acid, in which is set a hollow cylinder of zinc; within this is a porous cup, filled with strong nitric acid, in which hangs a slip of platinum foil. The hydrogen liberated in this case, passing into the nitric acid, takes some of its oxygen from it to form water, leaving it as nitric oxide, which at first dissolves in the acid, and when that is saturated escapes in fumes. The decomposition of the nitric acid developes an increase of force, which renders this the most powerful form of constant battery yet invented.

Fig. 97.
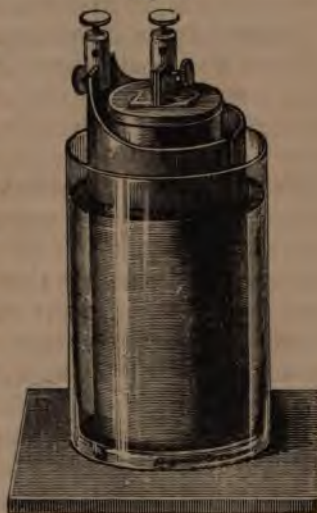
Bunsen's Battery.— This battery differs from the last only in the substitution of solid bars or cylinders of "gas-carbon" for the platinum foil. This is dictated by economy. The best form of this battery for rapid handling is that manufactured by Deleuil, of Paris. The cokes are hollow cylinders, very porous, and connection is made by copper plugs, which can be forced into the ends of these, and are joined to copper strips riveted to the zincs   Connections can be made and broken by this means with greater ease, certainty, and dispatch than

Fig. 98.

with the best form of binding screws; and this, in the management of a large battery, is of great importance. For telegraphic purposes, however, the battery made by Chester & Co., of New York, is better than this.

Modified Forms of the Bunsen Battery.—Chester & Co., of New York, manufacture a Bunsen battery, which answers very well for medical applications, in which the gas-coke is made into a cup in which the zinc is supported, the exciting fluid being a solution of sulphate of mercury. This gives off no fume and uses no seriously corrosive liquid. Its energy and constancy are increased by addition of a little table-salt. An ordinary Bunsen cell will act in a similar manner, for a short time, if the porous cell is removed, and a solution of glauber salt (NaO,SO_3) is employed as the only exciting liquid. (See Journal of the Franklin Institute of Pennsylvania, Vol. 50, p. 68, 1865.)

Chester & Co. also manufacture another form of the same battery, under the title of "electropoion battery." The important feature in this is the substitution of a mixture of sulphuric acid and solution of bichromate of potash for the nitric acid. This removes the difficulty of acid fumes, and relieves a great expense, the cost of this mixture being about one-tenth that of nitric acid. A good recipe for this mixture is this: in a gallon of water dissolve one lb. of bichromate of potash; to this add two pints of oil of vitriol. (See Journal of Franklin Institute, Vol. 50, page 68.)

This battery works very well with the Ruhmkorff coil, and also for the electric light.

The Iron or Maynooth Battery.—In this, each cell consists of an iron cup, containing a mixture of equal parts of nitric and sulphuric acids, within this is a porous cup, filled with dilute sulphuric acid, and containing a plate of amalgamated zinc. The best form of this battery is that manufactured by Bullock and Crenshaw, of Philadelphia,

in which the iron cups are rectangular, and the zincs of rolled metal.

This is the *cheapest form* of battery, and equal, if not superior, to any other of equal surface, in effect.

We must, however, in this connection remark that the mixture of strong nitric and sulphuric acids here used gives off a most acrid and irritating fume less during the action than during the charging and emptying of the battery. Arrangements should, therefore, be made for a strong draft or current of air to carry these fumes away from the operator during this process. The best plan is to conduct it in the open air.

The electro-motive forces of some of the preceding batteries have been estimated as follows:

Bunsen element	839	Smee	210
Grove	829	Hare	208
Daniel	470		

Besides those already mentioned, very many other combinations of solids and liquids have been suggested for galvanic batteries, but none others have proved in practice successful. Thus, we have copper and carbon with the mixture of bichromate of potash and sulphuric acid already mentioned. Copper and zinc with SO_3 and flowers of sulphur. The Bunsen solids with sesquichloride of iron, etc.

The Dry Pile, invented by Zamboni, consists of many thousands of alternate disks of zinc and silver paper; or of silver paper, with a paste of black oxide of manganese and gum, spread on the wrong side, without the zinc; arranged in a glass tube or other insulating support. (See Fig. 99.)

Fig. 99.

9*

The natural moisture of the paper here serves the office

Fig. 100.
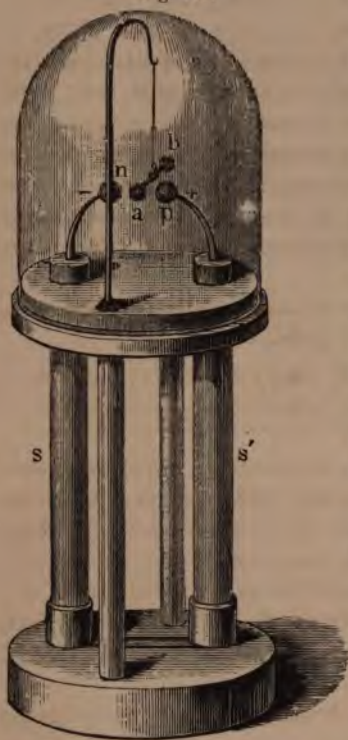
of an exciting fluid, and very intense, though feeble effects are produced. Thus, the extremities will attract light bodies, and even give minute sparks; exhibiting in fact rather the effects of statical, than of dynamical electricity. This results from the great number of ele ments, and bad conduct ing power of the pile, which favors a separation of the fluids, but not the establishment of a current. One of the piles, thoroughly dried, ceases to act; but recovers on exposure to moist air. A double column of this sort arranged as in (Fig. 100) will keep the light ball, a, vibrating between its poles for years.

Gas Battery. — See page 109.

Management of Galvanic Batteries. — Where a number of cells are to be used together, they should be united in different ways, according to the effects which we desire to obtain. If great resistances are to be overcome, as in the electric light, the heating of fine wire, etc., they should be placed in a series, as indicated by (Fig. 101), where a Bunsen battery is shown in ground plan, the

carbon of each cell being connected with the zinc of its
right hand neigh-
bor.   This gives
us a current of
intensity,   great
in proportion to
the   number   of
the cells (within certain limits), and of quantity, pro-
portional to the size of a single cell.

Fig. 101.

If the resistance to be overcome is very small, as when the
current has only to pass
through a short and good
conductor, the cells should
be united, as shown in
(Fig. 102), all the zincs
being joined together at
one side, and the carbons
at the other; then, con-

Fig. 102.

necting Z and C, we obtain a current, whose intensity is
only that of a single cell, but whose quantity is pro-
portional to the number of cells employed.
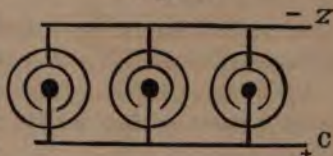
Usually we require in electrical apparatus, some in-
tensity, with as much quantity as we can get.   A good

Fig. 104.
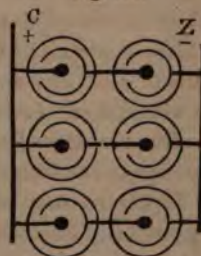
Fig. 103.

practical arrangement for ordinary apparatus is shown
(Fig. 103), and for a Ruhmkorff of 9 inch spark, or under,

in Fig. 104. For larger coils the series should be increased in quantity, but not in intensity, until we come to the large coils of 16 to 20 inches, when 15 cells should be used, in three rows, giving intensity of three, and quantity of five.

In setting up a nitric acid battery, it is most convenient to mix the dilute acid in the cells beforehand, then to put in all other parts, and make the connections; and lastly, to pour in the nitric acid. This prevents the dulling of the connections by fumes, and saves nitric acid; as the cells get soaked with the diluted sulphuric acid beforehand.

The mixed liquids to be used should *always* be mixed beforehand, and allowed to cool entirely.

In all large batteries the connections should have as much contact surface, and be as large in section, as possible.

After use, the battery should be taken apart, as soon as possible. More injury will occur to a battery, while standing disconnected, than when it is in active use; as the local currents have at this time full play. The zinc elements should be well washed, drained, and kept (apart from the other portions of the battery) in as dry a place as possible. The porous cells and carbons should be kept in water, if to be used soon again, and soaked for at least a week (in water frequently changed), before being dried and put away. To put away porous cells, etc. (which have been simply washed after use), in contact with the zinc elements, is to insure great injury, and perhaps even destruction, to the battery.

Carbons used with such batteries as that described, page 100, should be soaked in diluted nitric acid, when they become coated with a white deposit of oxide of zinc, or the like.

Amalgamation. — Zinc is the active element employed

in all batteries, and on account of certain impurities which cannot be removed, but by very expensive treatment, is subject to "LOCAL ACTION;" that is, a little speck of some foreign substance will form, with the zinc immediately around it, a little galvanic pair, which will cause a rapid corrosion of the zinc, formation of hydrogen bubbles, interference with, and opposition to the general current of the battery, and other evils. To remedy this difficulty, we resort to amalgamation; that is, coating the surface of the zinc with mercury, which unites with it, and practically excludes all such local action as we have described, preventing, in fact, to a great degree, any chemical action between the liquid and metal, until the entire galvanic circuit is closed, and the true chemico-electric action begins.

Batteries in use should be thoroughly amalgamated. This is best done some days before they are to be set up, as zincs freshly amalgamated, sometimes heat, and suffer local action, in an unaccountable manner.

Effects of the Galvanic Currents.

Heating and Luminous. — We have already noticed that a wire is heated by a current, which it is unable to conduct, and that the discharge of a battery of Leyden jars will thus fuse and vaporize gold, iron, platinum, etc. (page 83). Similar effects are produced by a galvanic current. Thus, the current from 40 Bunsen cells, 8 inches high, will keep 6 feet of platinum wire, No. 27, at a bright red heat, 3 feet at a white heat, and will fuse a shorter piece. By cooling part of the wire, as with a wet cloth, we make the rest hotter; because more electricity can pass by the cool wire, heat diminishing the conducting power. The surrounding medium has a certain effect on this experiment, for a draft of air will cool the wire; as

also will such a gas as hydrogen, on account of the mobility of its particles.

Luminous Effects. — When a very powerful series, of 30 or 40 elements, is terminated by points of dense carbon, and these, being first in contact, are separated a little, a most dazzling light is produced. In this case particles of the carbon are driven across from the positive to the negative pole, causing such vibrations as produce intense light to take place in both the points, and to some extent in the flying particles. This may be admirably shown where the points, regulated as they burn away by Duboscq's Electric Lamp, are placed in a lantern, and, through a diaphragm, throw an enlarged inverted image of themselves on the screen.

If the lower or positive point in the lamp is replaced by a cup of carbon, holding a fragment of

Fig. 105.

silver, and the discharge is taken from this, the light given off is green, the length of the discharge is increased 5 times, and the negative point becomes beaded with drops of liquid silver, carried over by the current. On the screen we see the image shown at Fig. 105.

The flame, emerald green, and like a tongue licking the point, now on one side, now on another: the points red, tipped with white, and the silver drops, like so many beads of dew.

This discharge, called the electric light, when produced from a single series of 48 Bunsen elements, is equal to 572 candles. By increasing the number of elements in series above this, the gain in intensity of light is small, though the arch of flame may be made longer; thus 46 elements give an intensity of 235, and 80 elements of 238. But by increasing the quantity, as by using three parallel series

of 36 elements, the intensity rises to 385 ; that of sunlight being 1000.

We have reason to believe, from certain spectral lines and fluorescent effects, that the *intensity* of heat and light in the electric discharge is greater than in the sun. See Paper by Wm. A. Miller, in Proceedings of Royal Institute, 1863, p. 47.

Chemical Effects of the Galvanic Current.

If the poles of a galvanic battery are placed in any compound fluid they tend to separate it into its constituents, the positive being attracted to and collecting around the

Fig. 106.

negative pole, and the negative about the positive pole Thus, if we have a U tube, with a solution of sulphate of soda colored by tincture of cabbage, and plunge two platinum strips, forming the terminals of a battery, in the ends, the acid or negative element of the salt will collect about the positive pole, turning the cabbage-purple red in that limb, while the alkali, or positive constituent, will collect about the negative pole, and turn the purple of that limb to a rich green. Again, if the fluid contains but two "*elements*," as water (consisting of oxygen and hydrogen),

these will likewise be separated and eliminated. Thus the glass vessel, Fig. 107, containing water, and having two platinum strips let into it below, connected with the battery, the oxygen will be given off at the positive pole, and the hydrogen at the negative, and these, rising in bubbles, may be collected in tubes arranged for the purpose.
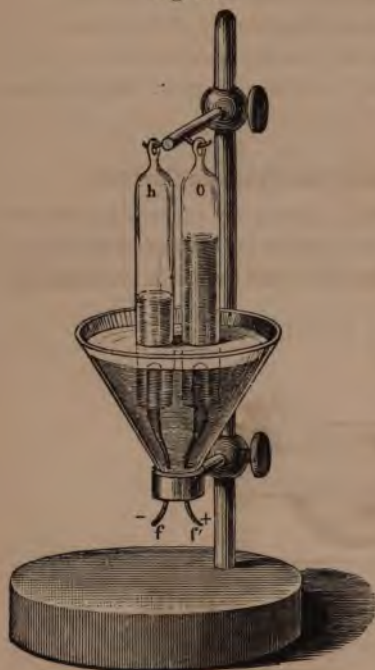
Fig. 107.

This action, called ELECTROLYSIS, is indeed our most potent means of effecting the decomposition of chemical bodies. Sodium, potassium, etc., were discovered by this means; by this means also we measure the quantity of a galvanic current, the amount of water decomposed, and of gas evolved, being in proportion to the quantity of the current passing, we therefore have an apparatus, arranged like the preceding, except that both gases are collected together and measured, the amount collected in a given time, indicating the quantity of the current. Figs. 108 and 109 show two forms of this apparatus. The first is the most complete and efficient, but the second is the simplest and most easy of construction. The cork and wires must be well coated with sealing wax.

Fig. 108.
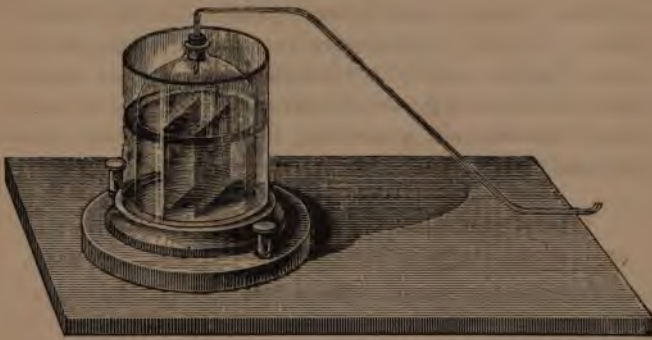
The great industrial application of this same action, in *electro-plating* and *gilding* and *electrotyping*, must not be forgotten. Here, the matrix or mould being made of, or covered with a conducting material, is suspended in a solution of the metal to be deposited, and made the negative pole of a galvanic series. The positive metal is then deposited on this in so solid a state as to form a complete plating, or

Fig. 109.

admit of being itself removed and used for printing, etc., as the case may be.

Gas Battery and Secondary Piles.

After the apparatus, Fig. 107, has been used for a few moments, if it is disconnected from the battery and connected with a delicate galvanometer, a current will be shown, op-

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posite to that of the original battery. This is produced
by films of oxygen and hydrogen attached to the platinum
plates.   On this principle Grove constructed his gas bat-
tery.   So also powerful "secondary piles" may be pro-
duced by immersing two or more plates of lead in a solu-
tion of Glauber salt, connecting the end plates with a bat-
tery, and after a time disconnecting.

Properties of Currents Moving Freely in Wires.

Magnetizing Effects. — We have already noticed that a
current passing around a bar of iron renders it a magnet,
permanently if the bar is of steel, temporarily if the bar
is of soft iron (page 92).   This action is well shown in
many pieces of apparatus, such as the divided ring, the
armature engine, &c.

Fig. 110.
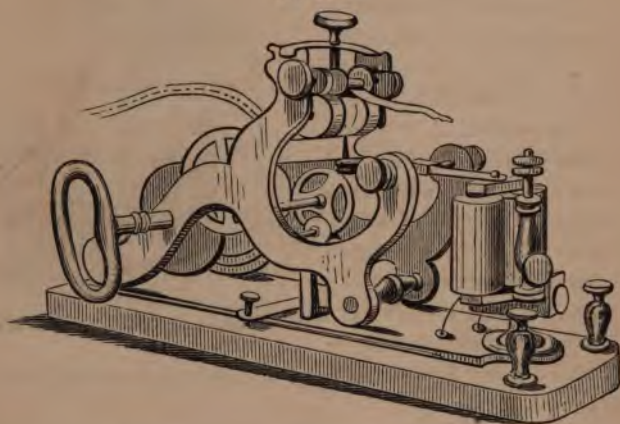
The most remarkable application of this action is, how-
ever, found in the first telegraph practically applied, i. e.
that of Morse (Fig. 110).   In this an intermittent current
(whose breaks and flows are controlled by an operator at

one end of a long circuit), causes, at the other end, an armature or bar of soft iron, attached to a lever, to be repeatedly attracted by an electro-magnet set beneath it, and thus makes a pencil at the other end of this lever produce upon a moving band of paper, dots by a short and strokes by a more continued pressure.   An alphabet of these marks being pre-arranged between two operators, communication may be thus made through great distances with indefinite velocity.

By ingenious and elaborate arrangements of mechanism, the message sent is automatically printed by the apparatus, as in the instrument of House or of Hughes, and is even in that of Bain reproduced in an *autographic copy.*

Velocity of Galvanic Currents in Good Conductors.

This, according to experiments of the U. S. Coast Survey, is about 18.700 miles per second in land lines, but through submerged cables the velocity is much less.

Magnetic Properties of Coils or Solenoids.

As might be anticipated from the theory of magnets, a coil or solenoid (Fig. 111) through which a current is passing, has all the properties of a magnet.   It will attract iron, repel with its poles the like and attract the unlike poles of magnets, arrange itself north and

Fig. 111.

south, and, in fact, comport itself in all respects like a magnetic bar.

Fig. 112.

Again, such a Coil will tend to draw into itself a bar of iron whose end is brought within its reach. This is well illustrated by the experiment of the suspended bar (Fig. 112), and by Page's coil engine, in which bars attached to cranks and alternately drawn into coils, are caused to operate machinery.

Again, such a Coil will cause a magnetic needle to stand at right angles to the planes of its circular currents. This principle is applied

Fig. 113.
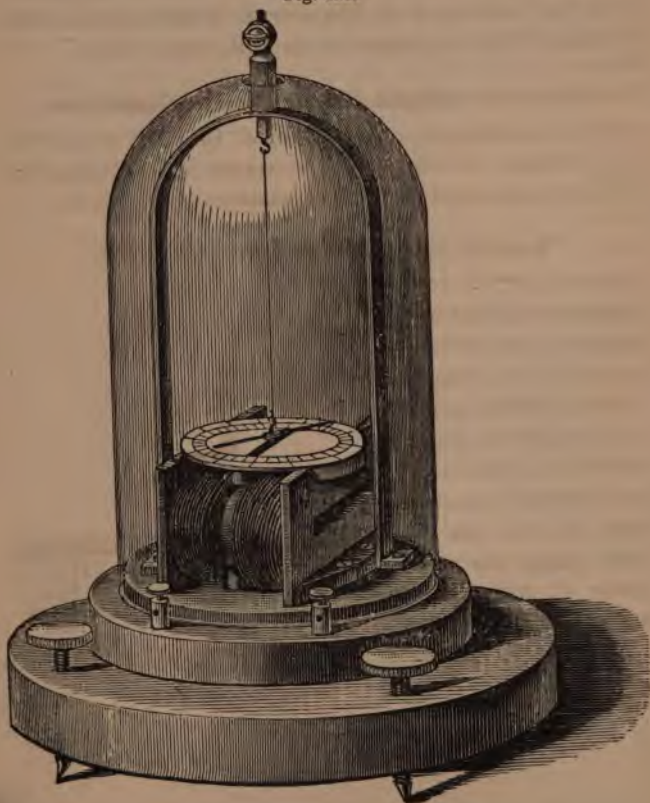
in the apparatus used for measuring the intensity of currents; for the amount of deflection will vary in a known ratio to the intensity of the current. For currents of small quantity the GALVANOMETER (Fig. 113) is used. This consists of a heavy flattened coil of wire, within and over which an astatic pair of needles is suspended. The deviation of these is noted on a circular graduated scale, when a current is passed through the coil by means of the binding screws.

For currents of great quantity we employ the **Tangent Compass** (Fig. 114), which consists of a band of copper, bent nearly into a ring, supported on a stand, with a binding screw attached to each end, and with a small compass-needle supported at the centre. With this instrument the *intensity of the current is proportional to the tangent of deflection* of the needle.

A Solenoid will be acted upon by a current in this, as in other respects, exactly like a magnetic needle. By reason of this "tangential force," also, a wire carrying a current tends to revolve about a magnet parallel, or nearly parallel to it.

Again, a Magnet will likewise rotate around a current—as may be proved in a similar manner—and also around a current, passed through half its own length.

Many effects similar to the foregoing may be developed by the magnetic action of the earth, and may be readily explained, on the principles already stated, by regarding the earth as a great magnet, with its north pole (in a magnetic sense) at the south, and the south pole at the north extremity of its axis.

Wires carrying currents in the same direction attract each other.

Wires carrying opposite currents repel each other.

A conductor carrying a current between the poles of a
10 *

Fig. 114.
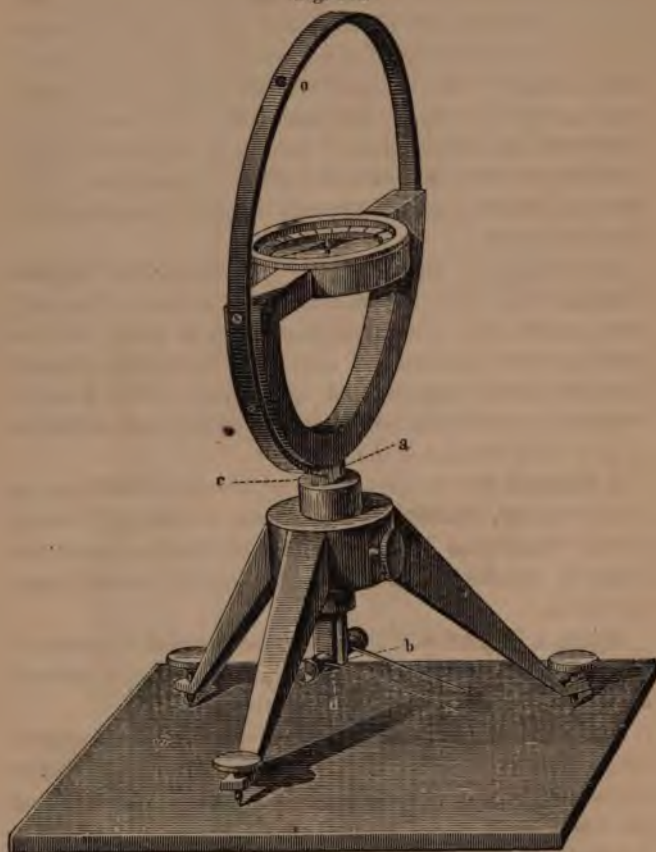
U magnet, at right angles to the line joining them, is re-
pelled.

Galvanic Induction.   By Currents and Magnets.—If two
wires are placed parallel to each other, and an intermit-
tent current is passed through one of them, at every in-
terruption of the flow an instantaneous "INDUCED or

SECONDARY CURRENT," coincident in direction with the first or "PRIMARY CURRENT," will be developed in the other wire. At every renewal of the primary, on the other hand, a momentary induced current will be developed in the other or "secondary wire," opposite in direction to the "primary."

These induced currents may be best shown by using coils or helixes of wire, wound on spools or bobbins. Thus we have a large bobbin of fine wire, A, for the

Fig. 115.

secondary, and a smaller one, B, of thick wire, fitting into the former, for the primary current.

These being put in place, and an intermittent current passed through B, the secondary, developed in A, may be demonstrated by connecting its ends with a galvanom-

eter, or by holding them in the hands, when a shock or series of shocks will be perceived.

A like effect would be produced if, in place of interrupting the current in B, we left it continuous, and then rapidly moved B out of and into A.

A magnet may be similarly used, as a substitute for B, being thrust into, and withdrawn from A, with the same

Fig. 116.
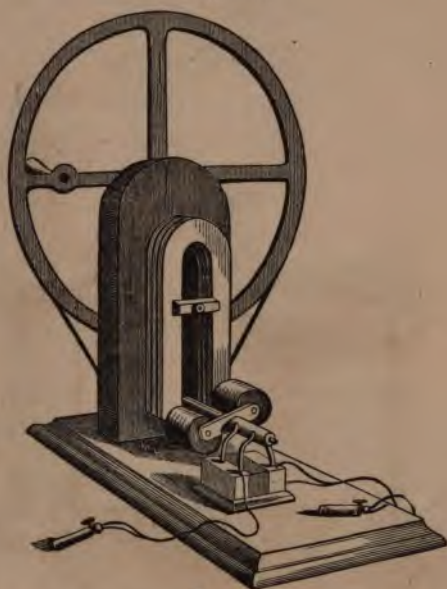
effect; or we may place a bar of soft iron in A, and then cause it to receive and lose magnetism by the approach and withdrawal of a permanent magnet. This will of course be precisely equivalent to inserting and withdrawing it. This is the principle of action in the magneto-electric machine, Fig. 116, and others of like nature. By such means, many magnets being employed, currents are oo-

tained capable of electro-plating on the large scale, of illuminating light-houses with the electric light, etc.

Lastly, we may put B in its place, insert a soft iron bar in the centre of it, and then pass a discontinuous current through B; we shall then have the combined inductive effect of the coil and magnet. This is realized in the ordinary medical induction coil (Fig. 117). A bar of iron may have excited on its surface an induced current, which interferes with its influence on the secondary coil.

Fig. 117.

For this reason a bundle of needles is more effective than a bar. If these needles are surrounded by a conducting envelope, such as a tube, their efficiency is again reduced, unless this tube has a longitudinal opening to interrupt its conducting power.

A secondary helix, like that just described, if made of very great size, constitutes the apparatus known as the Ruhmkorff coil. which yields a secondary current of so great intensity as to possess all the properties of statical

Fig. 118.
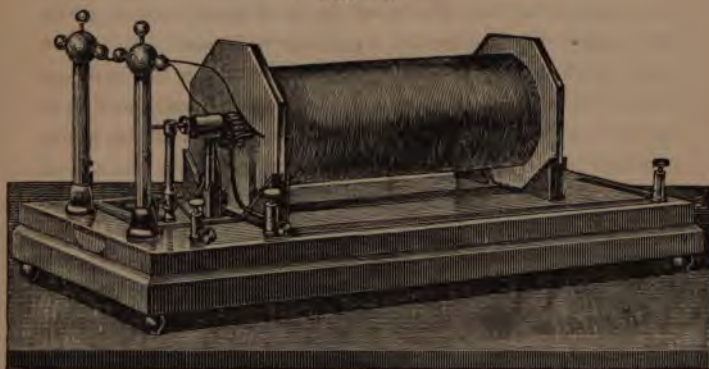
electricity.   This coil, as originally constructed by Ruhm-
korff, is shown (Fig. 118) as improved by E. S. Ritchie, Esq.,
of Boston, in Fig. 119. (See Franklin Institute Journal,
vol. 40, p. 64.)

Fig. 119.
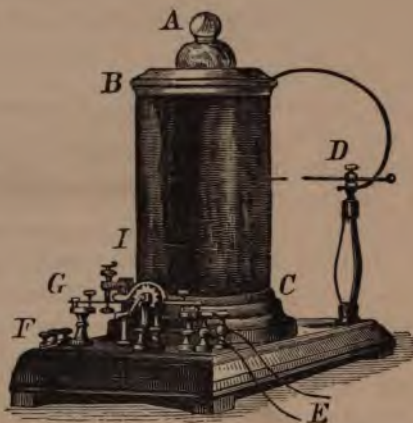
To both these coils, when a great resistance is to be
overcome, as when the spark is to be passed in air, the
"*condenser*" of Fizeau is an addition of great importance.
This consists of two sheets of tinfoil of great extent, 40 to
100 square feet, separated by oil or gummed silk, folded
away in compact form (in general, packed in the base on
which the rest of the apparatus is supported), and con-
nected with the *primary* circuit, at each side of the point
where it is interrupted.   This condenser delays the action
of the extra-current (to be presently described), and so
enables the electricity to collect and overcome a resist-
ance before this interfering action can take effect.   Where
the resistance is small, as in discharges in a vacuum, or
through good conductors, the condenser is not required.
The largest coils of this sort contain 30 miles of wire in
the outer helix, and give sparks of 20 inches in length.

This coil is at once the most convenient and powerful means of producing statical electricity within our reach. With 6 to 10 Bunsen cells, one of Ritchie's 6 to 15 inch coils will produce a continuous stream of sparks 6 to 15 inches in length; will charge a large Leyden jar, so that it will be discharged with a report like a torpedo many times in a second; and will operate all electrical vacuum experiments with a splendor and volume of light entirely unapproached by any other electrical apparatus. It is not, however, fit to perform experiments of attraction and repulsion, because the fluids are developed in it, not steadily, but in a series of instantaneous flashes.

The Extra-Currents.—This is the name given to induced currents, similar to those above described, which are developed in a *primary* wire at the moment of making and breaking connection. The *inverse* extra-current, developed at making connection, is of course overcome by the opposing primary then started; but the "*direct*" extra-current produced at breaking circuit, shows itself very fully. It occasions the bright spark seen at breaking connection, where the circuit passes by a long wire, especially if this is coiled, and may be made to give a shock, fuse platinum wire, etc., exactly as the ordinary induced current would.

It is often used in medical batteries, and is then generally called "the primary induced or Henry current."

Currents are also induced by magnets in moving conductors. Thus, a copper disk being rotated under a compass needle, will have currents developed in it, which, by their ac-

Fig. 120.

tion on the needle, will cause it to revolve about its point of support.

Again, a disk of copper rotated between the poles of a powerful magnet becomes very hot by reason of the currents developed in it; in fact, Tyndall using a brass tube in this way has melted fusible metal in it in 1½ minutes.

Thermo-Electricity.

If two different metals, such as Bismuth and Antimony, united at one point, be heated at this junction, a current of electricity will be established between them in one direction; if they are cooled in the same place the current will be reversed. If, therefore, many such bars be joined alternately, as in Fig. 120, heated at one side, A B, and cooled at the other, C D, a sort of battery will be produced, and a strong current obtained. The flow thus developed is called Thermo Electricity, but is in all respects identical with the galvanic current of the battery. In the following table many substances are arranged in order, from the most positive Bismuth to the most negative Tellurium. Any one of these will be positive to any below, and negative to any above it; that is, when heated with one below the positive fluid would pass to that other metal by the junction, and so on. Here, as in the battery, however, the positive pole will be connected with the negative terminal element
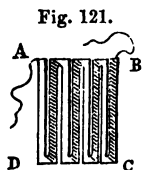
Fig. 121.

Bismuth,	Copper,
Nickel,	Platinum,
Cobalt,	Silver,
German Silver,	Zinc,
Brass,	Iron,
Lead,	Antimony,
Tin,	Tellurium.

According to Bunsen and Becquerel (see Jour. of Fr.

Inst., Vol. 49, p. 422), the most powerful series of any may be made of copper, pyrites, or sulphide of copper, and metallic copper.

This development of electricity by heat may be well shown by the thermo-electric revolving arch, Fig. 122, where the lamp, heating the junction of the brass ring with the iron arch, causes a current which rotates the frame, so as to bring the other junction into the lamp, when the same thing is repeated, and a rotatory movement is thus kept up.

Fig. 122.

This action, by which heat develops a galvanic current, is of great use in the measurement of very delicate variations of temperature; for by connecting a small thermo-electric combination or pile, as Fig. 123, with a delicate galvanometer, changes of temperature may be noted which would otherwise escape all observation. Such an arrangement is called a THERMO-MULTIPLIER, and is of inestimable value in most branches of physical research.

Fig. 123.
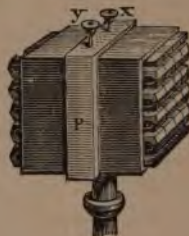
Animal Electricity.

Some fish, such as the Raia torpedo, and the gymnotus or electrical eel, by reason of a peculiar anatomical structure within their bodies, in some sort resembling a galvanic pile, develop notable quantities of electricity, so that they give a very severe shock if touched, and may be caused to magnetize a bar of iron, fuse gold-leaf, etc. Though this intense and special manifestation of electric

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disturbance is confined to a few creatures, provided with
a peculiar set of organs, electrical action goes on in some
degree in all living animals, and is closely connected with
their vital actions.   Thus electric currents can be proved
to exist in the muscles when these are in action, and a sort
of galvanic battery can even be produced by connecting in
order, many portions of muscular substance.

The subject of animal electricity, in its relation to phy-
siology, is one of great interest; but it is as yet too much
mixed with doubtful theory, and too extended in its scope
for discussion in this place.

PART II.

CHEMISTRY.

General Definitions.

Chemistry is that science which treats of the distinguishing properties of bodies and of their actions under the influence of CHEMICAL AFFINITY.

Distinguishing Properties are those possessed by certain substances exclusively, and by which they may, therefore, be recognized. Ex. Gold has a specific gravity of 19.26, a yellow color, and melts at 2016° F.; these properties make it distinguishable from other substances.

Chemical Affinity is that force of attraction which exists between the particles of substances of a different nature, causing them to unite so as to form compounds, having properties unlike those of the constituents.

1st. It acts between particles, i. e. only at insensible distances, thus requiring an intimate mixture or approach of particles to bring them within its range. Thus sulphur and chlorate of potash mingled in lumps effect no combination, but if ground together in a mortar a violent combination takes place (a few grains only should be used for this experiment). From this fact arises the utility of pulverization, fusion, and solution in conducting chemical actions.

(123)

2nd. It acts between substances of a different nature. Thus acids will combine with alkalies, and *vice versa*, but not acid with acid, or alkali with alkali. As a general rule, the more different the properties of the substances, especially in an electrical sense, the greater their force of combination.

3rd. It causes the formation of compounds with properties different from those of their constituents. These differences are chiefly in (*a*) Color, (*b*) State, (i. e. solid liquid or gaseous), (*c*) or in Temperature.

(*a*) To illustrate changes in color. Prepare seven glasses containing solutions in water of the following substances: I. Ferrocyanide of potassium. II. Chromate of potassium. III. A mixture of the foregoing. IV. Sulphocyanide of potassium. V. Hydrosulphate of Ammonium. VI. Sulphuric Acid. VII. Ammonia. To each of these add a solution of nitrate of lead containing a little sesquinitrate of iron. The colors then, originally light yellow or white, will become as follows: I. Blue, II. Yellow, III. Green, IV. Red, V. Black, VI. Milk-white, VII. Buff. *Two blacks make a white.* Make some ink in a glass by mixing in it tincture of galls and per-sulphate of iron. Drop into it some crystals of chlorate of potash. Make some common sulphuric acid black, by stirring it with a stick. Pour the black acid into the ink, and a clear solution like water will result.

(*b*) Changes in state. *Two solids make a liquid.* Grind together in a mortar crystals of NaO,SO_3* (6 parts) and $NH_4 O,NO_5$ (5 parts). They will form a liquid. Mingle a saturated solution of CaCl. with a little oil of vitriol diluted with half its bulk of water. These clear liquids will form an opaque solid. *Two gases make a solid.* Rinse one glass with a few drops of Ammonia and another with

* NaO,SO_3 = Glauber salt, NH_4O,NO_5 = Nitrate of Ammonia. CaCl = Chloride of Calcium.

Muriatic acid. Place their openings together; they will be filled with solid particles forming a dense cloud.

(c) Differences in temperature. Pour oil of vitriol into water, introduce a test tube containing water, and stir it about. The water in this will boil. Pour water on anhydrous CuO,SO_3* or on Lime (CaO.); both will become intensely hot and give off steam. The laws which govern this force will be found on page 295.

Substances are of two kinds:

Inorganic or mineral, as metals, gases, rocks, &c., and

Organic, or those connected with "life," as wood, flesh, &c.

Organic bodies differ from inorganic in so many ways that they are best considered separately under the head of Organic Chemistry. Moreover this branch of the subject can be developed more clearly after we have explained the laws which regulate the formation of the much simpler substances, in the domain of Inorganic Chemistry.

INORGANIC CHEMISTRY.

Inorganic bodies are either Elements, Binaries, Ternaries or Quarternaries.

1st **Elements** are those bodies which have never been decomposed or separated into others. Their number is about 65, of which 52 are METALS and 13 METALLOIDS or nonmetallic elements. The following table contains a list of these elements, with their symbols and atomic weights, combining proportions or equivalents. The names in brackets are those from which the symbols of certain bodies have been derived: 6 of these are metals known to the ancients and still retaining in this sense their Latin names, Sb Au Fe Pb Hg St. Two discovered in modern times follow their example, and one takes its name from a German mineral in which it was first found.

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* CuO,SO_3 = Sulphate of Copper.

Table of the Elements.

Names of Elements.	Symbols.	Atomic Weights.	Names of Elements.	Symbols.	Atomic Weighas.
Aluminum....................	Al	13.7	Nickel......................	Ni	29.6
Antimony (Stibium).....	Sb	120.3	Niobium	Nb	97.5
Arsenic	As	75	Nitrogen.....................	N	14 .
Barium	Ba	68.5	Osmium	Os	99.6
Bismuth......................	Bi	208	Oxygen......................	O	8
Boron........................	B	10.9	Palladium..............	Pd	53.3
Bromine................	Br	80.	Phosphorus	P	31
Cadmium	Cd	56	Platinum	Pt	98.7
Cæsium	Cs	133	Potassium (Kalium).	K	39
Calcium.....................	Ca	20	Rhodium.....	Ro	52.6
Carbon....	C	6	Rubidium.....	Rb	85.4
Cerium.....................	Ce	46	Ruthenium.............	Ru	52.2
Chlorine	Cl	35.5	Selenium	Se	39.3
Chromium...................	Cr	26.7	Silicon.....	Si	21.35
Cobalt.......................	Co	29.5	Silver (Argentum)....	Ag	108
Copper......................	Cu	31.7	Sodium (Natronium)	Na	23
Didymium............... .	D	48	Strontium.........	Sr	43.8
Erbium	Er		Sulphur....................	S	16
Fluorine	F	19	Tantalum.............	Ta	
Glucinum......	Gl	26.5	or Columbium......	Cb	68.8
Gold (Aurum).............	Au	197	Tellurium..............	Te	64.2
Hydrogen	H	1	Terbium.................	Tb	
Iodine .. ..,....	I	127	Thallium	Tl	204
Indium......	In	27.07	Thorium..............	Th	59.5
Iridium.......................	Ir	99	Tin (Stannum)	Sn	59
Iron (Ferrum)...........	Fe	28	Titanium...............	Ti	24.3
Lanthanum........	Ln	47	Tungsten (Wolfram).	W	92
Lead (Plumbum).........	Pb	103.7	Uranium.................	U	60
Lithium......................	Li	7	Vanadium	V	68 6
Magnesium.................	Mg	12	Yttrium	Y	32 2
Manganese...................	Mn	27.6	Zinc......................	Zn	32.6
Mercury (Hydrargyrum)	Hg	100	Zirconium..............	Zr	33.6
Molybdenum,.............	Mo	47.88			

Nomenclature of Elements.

Nomenclature of Elements. — Many elements bear in chemistry the same names as in common language. Ex. Zinc, Sulphur, Iron. Others are named from some striking peculiarity. Ex. Bromine derives its name from a Greek word meaning stench, in consequence of the disgusting odor it evolves. Others from the place or substance in which they were discovered. Ex. Columbium, because

it was found in an American mineral. Tantalum derives its name from tantalite, the mineral wherein it was first found. All the newly-discovered metals are made to terminate in *um* or *ium*. Ex. Platinum, Cæsium, Ruthenium.

Symbols of Elements.—A symbol is a letter or combination of two letters used to indicate one equivalent of the element for which it stands. We have therefore a symbol for each element, as O for Oxygen, H for Hydrogen, etc. The symbol is either the first letter or the first and characteristic following letter in the name of the element, as will be seen by reference to the above table. This second letter is added for distinction in those cases where the names of the two elements commence with the same letter. Thus, Carbon and Chlorine both commence with the letter C. In order to distinguish these two bodies, we must add the characteristic letter *l* in the name of the body last discovered, Chlorine, to its first letter C, so as to have a separate symbol, Cl, for Chlorine. It will be noticed that the second letter is added in smaller character; and, moreover, the definition of symbol, given above, makes it stand for only *one equivalent* of the element. O, for example, does not represent the substance Oxygen in general, but merely 8 parts by weight of Oxygen. F should not call to mind Fluorine, but 19 parts relatively by weight of Fluorine. Since a symbol stands for *one* equivalent of the element, we must place figures if we wish to indicate several equivalents: thus the symbol *Au* stands for 1 equivalent of gold. To represent 5 equivalents of gold we write 5Au. In writing the formulæ of compound bodies, however, the figure is placed after and a little below the symbol: thus the compound of Nitrogen, N, with 5 equivalents of Oxygen, 5O, is not represented by N5O, but by NO_5.

2nd. **Binaries.**— Binaries are compounds of two ele-

ments, They are divided into three orders: I. Acids;
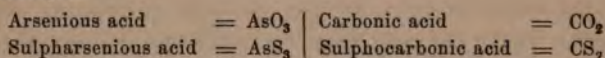II. Bases; and, III. Neutrals.

An Acid is a body having a sour taste, reddening a so-
lution of litmus, or of violets or red cabbage, and turning
a solution of cochineal yellow, and combining with bases
so as more or less to destroy their basic properties and to
form with them salts.

A Base is a body having a peculiar soapy taste, redden-
ing a solution of turmeric, turning one of violets or cab-
bage green, and one of cochineal purple; and combining
with acids to form salts, with mutual neutralization of
properties.

In both these definitions the last point only is universal
in its application. Alkalies are strong bases which fulfil
all the conditions above expressed.

A Neutral Body is one so devoid of all active properties
that it can scarcely be made to enter into combination. It
occupies an intermediate position between acids and bases.

I. **Acids** are again of three sorts. (*a*) Those contain-
ing Oxygen or Sulphur in union with a metalloid or
metal, as—

Arsenious acid	$= AsO_3$	Carbonic acid	$= CO_2$
Sulpharsenious acid	$= AsS_3$	Sulphocarbonic acid	$= CS_2$

(*b*) Those containing Sulphur, Selenium, or Tellurium, in
union with Hydrogen. (*c*) Those containing Chlorine,
Bromine, Iodine, Fluorine, or Cyanogen, in union with
Hydrogen.

(*a*). Acids of the first class, which contain Sulphur, are
distinguished from those containing Oxygen, by prefixing
sulph or *sulpho* to the name of the corresponding oxygen
acid; thus AsS_5 corresponds to AsO_5, Arsenic Acid, and
accordingly we give to the first the name Sulpharsenic
Acid.

The name of the oxygen acids themselves are derived
from the names of the metalloids or metals with which

the Oxygen is combined. Ex. The acid body formed by the union of Chlorine with Oxygen takes its name from the metalloid, and is called *Chlor*ic Acid.

When there are several compounds of Oxygen with the same element, the one which contains the most Oxygen is made to terminate in *ic;* the one containing the least in *ous*. If another acid is afterwards discovered, containing more Oxygen than the acid which was made to terminate in *ic, hyper* (abbreviated *per*) is prefixed to the new acid, to distinguish it from the acid first discovered. *Hypo* denotes less Oxygen than the remainder of the name implies. The above rules are exemplified in the following series of acids :—

Perchloric acid	$=$	ClO_7	Chlorous acid	$=$	ClO_3
Hypochloric acid	$=$	ClO_4	Hypochlorous acid	$=$	ClO
Chloric acid	$=$	ClO_5			

(*b* and *c*) The names of acids of the second and third class are formed by prefixing *hydro* to the name of the electro-negative element.

(*b*) Hydrosulphuric acid $=$ HS	(*c*) Hydrochloric acid	$=$	HCl
Hydroselenic acid $=$ HSe	Hydrofluoric acid	$=$	HF
Hydrotelluric acid $=$ HTe	Hydrocyanic acid	$=$	HCy

And it will be noticed that the symbol likewise of the electro-negative element is written last in the above examples.

II. **Bases** are named from both elements which compose them, the more electro-negative being named first. Ex. Oxygen being negative to iron, these when united form Oxide of Iron.

In writing the formulæ of bases, however, the symbol of the electro-negative is placed last. Thus we express this same substance, Oxide of Iron, by FeO.

If the compound contain one equivalent of the electro-negative element to each equivalent of the electro-positive

one, *prot* or *proto* is prefixed to the name of the negative element; if 2 equivalents of the negative to each of the positive, *deut, deuto, bi,* or *bin* is prefixed; if 3 negative to 2 positive, *sesqui;* if 3 negative to each positive, *trit, trito,* or *ter;* if 4 negative to each positive, *quad* or *quadro;* if 5 negative to each positive, *pent* or *penti.* Ex. FeO, 1 : 1 ; Protoxide of Iron, FeO_2, 1 : 2 ; Binoxide of Iron, Fe_2O_3, 2 : 3 ; Sesquioxide of Iron, FeO_3, 1 : 3 ; Teroxide of Iron.

III. **Neutral Bodies** are of two kinds. 1st. Those formed by the union of a halogen* body with a metal; they are marked by peculiar characteristics, and are known as Haloid Salts. 2nd. All other compounds of two elements which are neither acids nor bases. Both classes are named exactly like bases. Ex. NaCl, Chloride of Sodium. MnO_2, Binoxide of Manganese.

3rd. **Ternaries.** — Consist of an acid and a base. The negative element, in both acid and base, must be the same. Ex. Arsenate of Potassa, KO, AsO_5. Sulpharsenate of sulphide of potassium, KS, AsS_5. Every such union of an acid with a base is called a Salt. If an oxygen acid is united with an oxygen base, we have an Oxygen Salt; if a sulphur acid with a sulphur base, a Sulphur Salt. An oxygen salt is named by giving the name of the acid first, with its termination changed from *ic* to *ate,* and from *ous* to *ite,* and then adding the name of the positive element in the base, " oxide of" being understood. Ex. Sulphate of Iron, FeO, SO_3. A sulphur salt is named in the same way, but " sulphide of" is expressed. If the acid be to the base in the ratio of 1 : 1, *proto* is prefixed to the name of the salt; if as 2 : 1, *bi;* if as 3 : 2, *sesqui,* etc. Salts are divided into three classes: 1st. Acid Salts. 2nd. Neutral Salts. 3rd. Basic Salts. See page 179.

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* Halogen, from ἁλός, salt; γαννάω, *I produce.* They are Chlorine, Bromine, Iodine, Fluorine, and Cyanogen.

Sym. O.   **OXYGEN.**   Eq. 8.

Oxygen was discovered, independently of each other, by Priestley and Scheele, in 1774. It was called by Priestley "dephlogisticated air," and by Scheele "Empyrean air." Its true nature was pointed out soon after by Lavoisier, to whom it owes its present name of oxygen, ὀξύς acid, γεννάω, I produce. Because it was supposed to form all acid compounds. This idea is in a general way correct, but by no means universally true. Most acids contain O, but many do not.

Sources of O. — Oxygen constitutes 46 per cent. by weight of all the principal rocks, granite, basalt, gneiss, sandstone, and limestone ; 30 per cent. of all the common metallic ores; one-fifth of the atmosphere, and eight-ninths of all water.

Preparation of O. — 1st. By heating Red Oxide of Mercury to 750° Fahr., $HgO = Hg + O$. This process may best be exhibited by placing a little HgO in a test tube, supporting this in the retort holder, as in Fig. 124, and heating the oxide by means of a Bunsen burner, or powerful Argand lamp, such as in Fig. 125. The decomposition soon begins. Metallic Mercury is deposited in the cooler portion of the tube, and the escaping gas will relight an extinguished match, with a coal yet on it, if plunged in the mouth of the tube.

2nd. By heating to redness Black Oxide of Manganese, $MnO_2 = MnO + Mn_2O_3 + 2O$. This requires an iron vessel and the heat of a good fire.

3rd. By heating Chlorate of Potash which gives off 39 per cent. of O, $KO,ClO_5 = KCl + 6O$. Half an ounce of KO,ClO_5 yields 270 cubic inches, or nearly a gallon of O. A pound yields about 30 gallons.

4th. When a little Black Oxide of Manganese is mixed with Chlorate of Potash, the Oxygen is disengaged at a

Fig. 124.

much lower temperature than otherwise. The Oxide of Manganese undergoes no change and seems to act solely by its presence.

The operation may be well conducted on the small scale in a glass flask heated by a spirit lamp with an "Argand" or large hollow cylindrical wick, as is represented in Fig. 125, the gas being collected as it forms, in a bell jar filled with water, and inserted over a pneumatic cistern. An India-rubber tube serves best to convey the gas from the flask to the cistern. In making large quantities of oxygen it is best to use a copper flask of one quart or more capacity, heated by a Bunsen burner which should be removed as soon as the gas begins to come over freely; the operation will then continue to the end without further heating. The gas may then be collected in a gas bag made of strong India-rubber cloth, after passing through

Fig. 125.

a large washing bottle, or in such a receiver as is shown in Fig. 126, or Fig. 141.

Fig. 126.
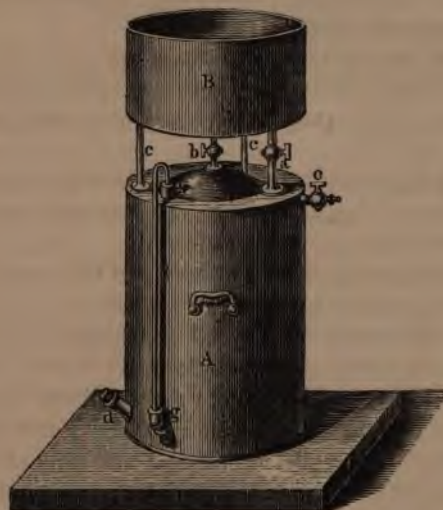
To use the gas receiver, Fig. 126, we fill A with water by pouring it into B, opening the stopcock *a* to admit it to

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A, and the cock e to allow the air to escape. Then both these cocks being closed, we remove the cork from d, and pass in, through this passage, the tube carrying the gas from the flask. As the gas enters it displaces the water, which then runs out around the entering tube at d, c c are merely iron rods supporting B. If after A is full of gas d is closed, B filled with water, a bell-jar full of water placed in B, and the cocks a and b opened, water will flow through a into A and drive out gas through b into the bell jar.

5th. By strongly heating Red Lead, $2PbO,PbO_2$, or almost any deutoxide of a metal, the oxide will be reduced to a protoxide, yielding oxygen.

6th. By heating Nitrate of Potash (Nitre), $KO,NO_5 = KO,NO_3 + 2O$.

7th. By heating a mixture of 2 parts strong Sulphuric acid (oil of vitriol), and 1 part black Oxide of Manganese, $MnO_2 + SO = MnO,SO_3 + O$.

8th. By heating 4 parts of Sulphuric acid with 3 parts of Bichromate of Potash, $KO,2CrO_3 + 4SO_3 = KO,SO_3 + Cr_2O_33SO_3 + 3O$. One ounce of salt yields 200 cubic inches of O.

9th. By heating Hydrated Protoxide of Barium in alternate currents of air and steam, when it will take O from the air and yield it to the steam.

10th. By heating Nitrate of Soda and Protoxide of Zinc.

11th. By adding to Hypochlorite of Lime in solution (obtained by mixing commercial bleaching salt or chloride of lime with water, and decanting or filtering through a cloth) a few drops of nitrate of cobalt, and gently heating. In this case the oxide of cobalt which is formed, abstracts oxygen from the hypochlorous acid and lime (leaving at last but chloride of calcium), and then in turn abandons this oxygen only to seize upon a fresh quantity.

A pound of Chloride of Lime (commercial) treated with about a quart of water will yield in this way $2\frac{1}{2}$ gallons

of oxygen. This process is a curious one, perfectly safe and easy to manage, but cumbrous where large quantities of gas are required, and no cheaper than the 4th. (See Journal of Franklin Institute, Vol. 50, p. 285.)

12th. By heating together Silica (sand) and Sulphate of Lime (plaster of Paris), $SiO_3 + CaO,SO_3 = CaO,SiO_3 + SO_2 + O$. Silicate of lime is formed, and Oxygen with Sulphurous acid passes off. The SO_2 is removed by liquefaction or absorption in milk of lime, and the O thus obtained pure.

Of all these methods the 4th is at present the most available.

Properties.— Oxygen is a gas, incapable of liquefaction by cold or pressure, and without color, taste, or smell. Its density is 1.1057; 100 cubic inches at 60°, and 29.988 inches barometric pressure, weigh 34.29 grains. It is slightly soluble in water, the latter dissolving at the ordinary temperature $\frac{1}{27}$ of its volume of gas. It is the most magnetic of gases (see p. 92); in this respect the O of the atmosphere is equivalent to a shell of iron enveloping the earth, and $\frac{1}{250}$ of an inch thick; and by its changes of magnetism, due to those of temperature, produces the diurnal variations of the magnet. It is the great *supporter of combustion.* Almost every case of combustion consists in a union of the elements of the burning body with Oxygen. When bodies burn in the air the great excess of nitrogen present carries away much of the heat generated, but when oxygen alone is collected in a receiver, the heat developed by combustion can rise much higher, and the more ready supply of the "supporting body" will greatly intensify the action.

This is well exhibited, as follows:

We fill bell-jars, such as Fig. 127, with this gas over the pneumatic tank, by filling them first with water, and then allowing the gas to flow into them from a tube intro-

duced under their immersed lower edge. (See Fig. 125.)
We then attach to wires, or place in copper spoons, as
their nature requires, pieces of charcoal, candle, sulphur,
phosphorus, etc. (dry sand should be placed in the spoon,

Fig. 127.

under the phosphorus), and ignit-
ing, plunge them into the jars
through their upper openings.
These bodies then burn with
great splendor.

To burn iron, or rather steel,
we use an uncoiled watch-spring,
which can be best ignited by the
oxyhydrogen blowpipe, and then
plunged in a jar of oxygen, or we
may fuse a little sulphur fast to its end, light this, and
then plunge it into the gas.

Figure 127 represents phosphorus burning in oxygen;

Fig. 128.

and Fig. 128 steel, in like case. Ere-
macausis is the name applied to a very
slow combination of bodies with oxy-
gen, by which no light is evolved.
This we see in decaying wood, and
vegetable matter generally, in the res-
piratory process of animals, etc. Oxy-
gen drawn into the lungs is absorbed
in the blood, and there combines with
various dead matter, exhausted tissue,
and the like, so producing heat needed for the support of
animal life.

Ozone and Ant-Ozone.—Besides its usual state, Oxygen
has two other and dissimilar conditions designated by
the above names.

When dry air or oxygen is passed through a glass tube
containing a number of fine wires coated with glass,
which form the poles of a Ruhmkorff Coil, the character

of the gas is changed. If it is passed through a strong solution of Iodide of Potassium (KI), part of it will be absorbed, setting free the Iodine. This is the Ozone. Another part will pass on unabsorbed, and may be collected with the gas which may have escaped action in a *dry* vessel.

Its chief peculiarity is that in the presence of moisture or water, it forms with it a dense white cloud or fume, which subsides after half an hour or so, leaving the water and common oxygen. This substance so acting is called Ant-ozone. These were discovered by Schönbein, and have been thoroughly studied by Meissner. (See Silliman's Journal, Vol. 37, p. 325, 1864, for a review of Meissner's book.)

Ozone is prepared, not only by the action of electricity on air, but also in the electric decomposition of water (page 108); by the action of phosphorus, partly covered with water, on air; by the action of ether, turpentine, etc., on air; by action of oil of vitriol on chameleon mineral (Silliman's Journal, 1863, Vol. 35, p. 111); and by plunging a red-hot glass rod into a glass having a few drops of ether in it.

Its test is paper moistened with starch, containing a little KI (starch, 5 parts; Iodide of Potassium, 1 part; to be boiled), which it turns purplish blue, or the juice of mushroom, Boletus luridus, Boletus cyanescenus, etc., or the alcoholic solution of the resin of Guaiacum, to which it communicates a blue color.

The properties of ozone are like those of oxygen, but in all respects more intense. It has a peculiar smell, suggestive of scratched varnish, which may be easily perceived in the vicinity of a powerful Ruhmkorff coil or electrical machine. It interferes with vegetation, formation of mould, etc.

Antozone may be prepared, not only in the way above

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described, but by action of dilute Sulphuric acid (SO_3) on Deutoxide of Barium (BaO_2) diffused in water at a low temperature, and by passing Carbonic acid (CO_2) through BaO_2 diffused in water. In this case, however, the Antozone at once unites with water forming HO_2. Antozone again seems to exist in Fluor Spar of Welsendorf, HO_2, being formed by grinding this mineral with water.

Test.—Antozone will develop the blue purple in starch containing KI, if very dilute solution of Sulphate of Iron (FeO_2SO_3) be first added to that mixture.

Ozone is often indicated by the symbol $+ O$, and Antozone by $- O$, and these are sometimes called positive and negative oxygen.

Sym. H.   **HYDROGEN.**   Eq. 1.

Hydrogen was discovered by Cavendish, in 1766. Its name is derived from ὕδωρ, *water;* and γεννάω, *I produce.* It constitutes one-ninth of all water, and part of most animal and vegetable bodies.
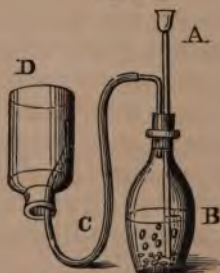
Preparation.—We always obtain H from water.

1st. By decomposing it with Sodium. Invert a test tube filled with water in a dish of the same, introduce a pellet of Sodium (Na) under it between the blades of

Fig. 129.

Fig. 130.

scissors, the Na will soon escape and float on the water

in the tube, setting free H, which will thus fill the latter. (Fig. 129.)

2nd. By passing steam over iron filings placed in a tube and kept at a red heat by a furnace.

3rd. By decomposing water acidulated with sulphuric acid with zinc ($HO,SO_3 + Zn = ZnO,SO_3 + H.$)

This operation may be conducted in a "gas bottle," Fig. 130, the acid and water (mixed before and allowed to cool) being introduced by the long funnel, and the gas escaping by the bent tube. Or to make the process self-regulating, we may employ the apparatus represented in Fig. 131, where the gas, generated by the contact of the acid water with the zinc, h, if not allowed to escape, col-lects in the bell jar, displacing the acid solution from the zinc, and so stops the action until the gas is allowed to escape, admitting the liquid when the operation recom-mences. Such an apparatus, made of copper and of large size, is very convenient to work the oxyhydrogen blow-pipe, lime-light, etc. The bell in this case had better float loose in the outer jar or reservoir, and have a capa-city of 6 gallons. The charge should be a bucket of water and 6 lbs. of oil of vitriol, which will yield more than 70 gallons of Hydrogen. Enough to run a powerful lime-light for two hours.

Fig. 131.

4th. By electrical decomposition of water (see page 108). When prepared by this means, the hydrogen has its affini-ties exalted so that it will decompose Sulphate of silver. (Smithsonian Reports, 1862, p. 397.)
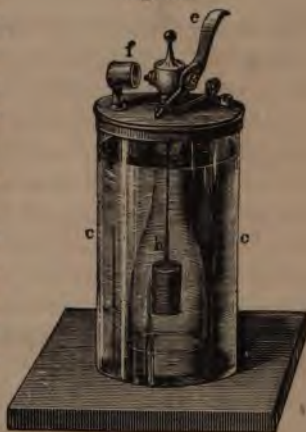
Properties.— Hydrogen is a gas, colorless, transparent, tasteless, and inodorous; it has a higher refractive power than any other gas; it is the lightest known substance, weighing little more than $\frac{1}{14}$ as much as air.   Density, 0.0692. One hundred cubic inches weigh 2.14 grains.   On account of its lightness balloons have been filled with it, and soap bubbles so charged rise in the air.   It may be collected by displacement (see Fig. 130), and poured *upwards* from one vessel into another.

The extreme rarity of hydrogen was strikingly demonstrated in the attempts which were made to condense it to a liquid, by great pressure in iron receivers.   The hydrogen *escaped through the pores of the iron.*   Ex. If a sheet of paper is placed at a little distance from the jet of a hydrogen generator, the current of gas will pass directly through the paper without altering its direction, and can be lighted upon the opposite side of the sheet.

Hydrogen is combustible, burning with a bluish flame, giving little light but intense heat. If a long glass, or other tube, is placed around a small jet from which H. is burning, the supply of air being thus limited the burning will be reduced to a series of slight explosions, which will develop a musical sound.   This arrangement has, therefore, been called the HYDROGEN ORGAN.

The Oxyhydrogen Blowpipe, invented by Dr. Robert Hare, in 1802, consists of two concentric nozzles with other parts, by which a jet of oxygen is introduced into the centre of a jet of burning hydrogen.   The most combustible body is thus supplied with the best supporter of combustion, and the heat evolved by their union is concentrated in a small space.   Its intensity is therefore very great.   Silver, gold, platinum, etc., are fused and vaporized, iron, zinc, etc., burned with brilliant effect, and other results of a high temperature attained.

The Lime-light. — When the oxyhydrogen flame is di-

rected upon a block of lime, this solid serves as a sounding-board to its intense vibrations; and enables them thus to develop a light of great brilliancy. For the best effect, the pressure on the gases should not be less than ¾ lb. per square inch, or 18 inches on a water gauge. If these two gases, O and H, are mingled in atomic proportions (by volume, 1 to 2; by weight, 8 to 1) and ignited, they will explode with violent detonation, though relatively little force. This is well shown by blowing bubbles in soapy water with the mixed gases (from a bladder, gas-bag, or other receptacle), filling the hand with these and firing them. They will make a loud report, but will produce no sensation to the hand. The detonation is caused by the instantaneous condensation of the vapor of water, which is produced by the combination of the two gases in contact with cold air. The water occupying, when condensed, a volume 1700 times smaller than when it was in the state of vapor, leaves a large vacuum. The rushing of the air from every quarter with great rapidity into this empty space, causes the detonation.

Compounds of Hydrogen with Oxygen.

I. **Water.**—Symbol, HO. Equivalent, 9. Sp. Gr. as Vapor, 0.622; as Liquid, 1.000; as Ice, 0.94.

Properties. (a) *Physical.*—Clear, colorless, tasteless, inodorous, transparent liquid. Below 32° it freezes into a variety of crystalline forms derived from the rhombohedron and six-sided prism. Evaporates at all temperatures, and under the usual pressure of the atmosphere boils at 212°. Reaches its maximum density at about 40°, and expands whether cooled below, or heated above, this point. In changing to ice, it becomes lighter and increases in volume; and we therefore see why:

1st. Ice forms only on the top of streams. If water followed the same law as almost all other liquids, and

became heavier in freezing, our rivers would be frozen solid from bed to surface, the fish they contained destroyed, navigation would be interrupted for most of the year, and all the heat of a summer sun would scarcely suffice to make the streams liquid again.

2nd. A *frost*, by changing the water contained in the cellular tissue of fruit to ice, bursts the delicate cell structure and destroys the fruit.

3rd. Water pitchers, fountains, water-pipes, drains, etc., burst in winter time, and *frost-stones*, or those very porous to water, crumble away.

Its density at 60° is taken as 1.000; and with this standard the specific gravities of all liquids and solids are compared. One cubic inch of water at 62°, weighs 252.456 grains. A gallon (imperial) contains 10 lbs. Avoirdupois = 70.000 grains, or 277.19 cubic inches of water.

Air dissolved in Water.—The presence of air in water which has been exposed to the atmosphere, is readily shown by suffering some water to stand for a time in a quiet tumbler. Bubbles of gas collect on the inside of the glass; accurately, the amount of air is about 3.2 volumes to every 100 volumes of water. But this dissolved air is much richer in oxygen than atmospheric air, and contains 33 volumes of oxygen to 100, instead of the 21 volumes which are found in the atmosphere. This excess of oxygen is due to its being more soluble in water than nitrogen. Ex. Fishes, which breathe the air dissolved in water by means of their gills, die in distilled water. Spring waters derive their sparkling taste and invigorating qualities from the air which they hold in solution.

Other bodies found in water.—*Rain-water*, in its passage from the clouds, carries with it, in solution, all the substances which are found in the atmosphere; such as oxygen, nitrogen, carbonic acid, traces of nitric acid, of carbonate and nitrate of ammonia.

Spring and *well* water, which is rain-water drained from porous soils or rocks, contains, in addition to the above substances, various salts which it has dissolved out from the ground; such as chlorides, sulphates, and carbonates of lime, magnesia, soda, potassa, and alumina. A small quantity of lime-salts is thought to render drinking-water more wholesome, and to aid in building up the bony structure of the body.

(*b*) *Chemical.*—Is the best solvent. Perfectly neutral; uniting with most acids and bases. When combined with a powerful acid, it supplies the place of a base, and is called *basic* water. In combination with a powerful base, it supplies the place of an acid, and is called *acid* water. Bodies combined with water are termed *hydrates*; uncombined, *anhydrous*. If the water existing in a crystallized salt can be driven off by heat without decomposing the salt, it is termed *water of crystallization;* if it cannot, *water of constitution.*

II. Binoxide of Hydrogen—$HO_2 = 17$. Sp. Gr. 1.453.

Preparation.—Successive portions of Binoxide of Barium are added to Hydrofluoric acid. $BaO_2 + HF = BaF + HO_2$. The insoluble Fluoride of Barium is removed by filtration, and the Binoxide of Barium remaining in the liquid, concentrated by evaporation in vacuo.

Properties.—A syrupy, colorless liquid, with an astringent and somewhat metallic taste; bleaching litmus and other vegetable colors instantly. At 79° slowly decomposed into oxygen and water; at 212°, with explosive haste. Many metals and metallic oxides instantly effect a like decomposition without themselves undergoing change.

Sym. N. NITROGEN. Ex. 14.

Discovered by Dr. Rutherford, in 1772. Shown to form part of atmosphere by Lavoisier, in 1775. Called by the French azote (lifeless); from α, privative, and ζοε, life. Its

name, nitrogen, is from *νίτρον*, *nitre*, and *γεννάω*, *I produce*. Occurs as four-fifths of the atmosphere, and in mineral and animal substances.

Preparation. — 1st. By burning phosphorus in an inclosed portion of air over water. N and $5\,O + P = N + PO_5$. 2d. By passing chlorine through aqua ammonia. $NH_3 + 3\,Cl = 3\,HCl + N$. 3rd. By heating solution of nitrite of ammonia $NH_4O,NO_3 = 4\,HO + 2\,N$. 4th. By heating solution of nitrite of potassa with sal ammoniac. $KO,NO_3 + NH_4Cl = KCl + 4\,HO + 2\,N$.

Properties. — These are all inert and negative. A gas without color, taste, smell, or capability of liquefaction, and solidification; density 0.972; does not support combustion, animal life, or enter, of its own accord, into combination.

Mixture of Nitrogen with Oxygen.

Atmospheric Air. — Density at 60° taken as 1.000, and with this standard the specific gravities of all other gases are compared; 100 cubic inches weigh 31.0117 grains. Consists, by weight, of 23 parts oxygen, and 77 parts nitrogen; by measure, of 21 parts oxygen, to 79 parts nitrogen. There is also about one-thousandth part of carbonic acid gas, a trace of ammonia, and some vapor, varying greatly in quantity with the temperature.

Regnault's Hygrometer. — The amount of moisture in the air, of course, affects its power of taking more, or of promoting evaporation. The dryer the air, the more rapid will be the evaporation taking place in it at equal temperatures. We can thus determine the amount of moisture in the air by means of this action, as follows. We have two thermometers (*t t*), supported near each other, one, however, plunged in a vessel of ether, A, through which air is drawn, by means of the aspirator,
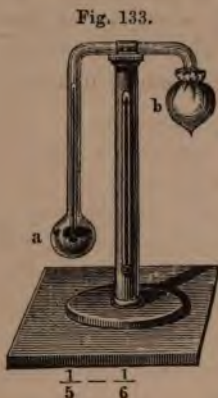
D. The dryer the air, the more the ether evaporates, and, therefore (see p. 32), the lower the temperature in A (indicated by one thermometer) falls below that of the air around indicated by the other. This difference in temperatures enables us to judge of the amount of moisture in the air.

Fig. 132.
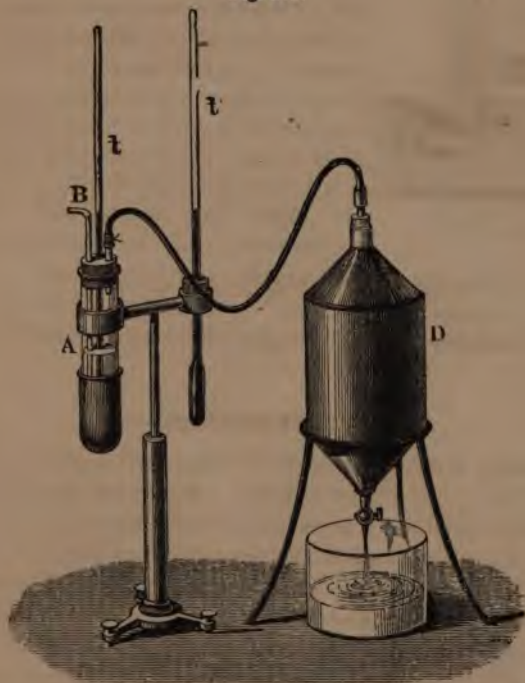
The aspirator, D, is used in many cases where we wish to produce a steady flow of air through a piece of apparatus, as in some cases of analysis, the determination of the Carbonic acid in the air, etc.

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The Dew Point is that temperature at which the mois-
ture present in the air is enough to
saturate it, and would begin to be
deposited from it as dew. This is
directly shown by Daniel's Hy-
grometer. (Fig. 133.)   This con-
sists of a little cryopherous (see page
31), with a thermometer in one bulb,
a, and a piece of cloth around the
other, *b*.   By pouring ether over *b*,
we so promote evaporation in a, that
its surface is cooled to the dew point,
and we see a misty deposit forming
on *a*, which is coated with gold leaf,
to show this the better.   The
temperature of the thermometer
in *a*, at the time this happens, gives us the dew point.
This temperature is "high," or near that of the air, in
damp weather; "low," or much below it, when the air
is dry.

Fig. 133.

$\frac{1}{5} - \frac{1}{6}$

Compounds with Oxygen.

Nitrous Oxide, Protoxide of Nitrogen, Laughing Gas
(NO; Eq. 22).   Sp. Gr. 1.525.   Colorless, transparent,
sweet-tasting gas; liquefiable at 45° under a pressure
of 50 atmospheres; a candle or phosphorus burns fiercely,
when plunged in this gas.   Its solubility diminishes
rapidly with increase of temperature; 100 cubic inches
of water, at 32°, dissolving 130 cubic inches of the gas;
and at 75°, only 60 cubic inches.   It intoxicates when
inhaled, and produces insensibility to pain.   Prepared by
heating nitrate of ammonia, $NH_4O,NO_5 = 4\,HO + 2\,NO$.

Nitric Oxide, Binoxide of Nitrogen, NO_2.   Obtained by
acting upon copper, with dilute Nitric acid. $3\,Cu +$
$4\,NO_5 = 3\,(CuO,NO_5) + NO_2$.   Colorless; in contact with

air or oxygen is converted into a deep-red gas, which is the vapor of hyponitric acid, $NO_4 = NO_2 + 2O$. Extinguishes a candle, but causes phosphorus to burn brilliantly.

Nitrous Acid—NO_3. An orange-red vapor, obtained by mixing 4 volumes binoxide of nitrogen, with one volume oxygen. $NO_2 + O = NO_3$. In contact with water, decomposed into Nitric acid, and Binoxide of Nitrogen, $2HO + 6NO_2 = 2(HO, NO_5) + 4NO_2$. On account of a like action, it cannot be made to unite directly with metallic oxides; the various nitrites are formed by heating corresponding nitrates; thus, $KO, NO_5 = KO, NO_3 + 2O$, oxygen being evolved.

Hyponitric Acid — NO_4. A deep red vapor, at common temperatures, at $0°$, an orange liquid; obtained by heating nitrate of lead. $PbO, NO_5 = PbO + O + NO_4$.

Nitric Acid—NO_5. A crystalline solid, obtained by passing dry Chlorine over well dried Nitrate of Silver, $AgO, NO_5 + Cl = AgCl + O + NO_5$.

Hydrated Nitric Acid—HO, NO_5. The Hydrated acid is always meant when Nitric acid is spoken of, because Anhydrous Nitric acid is utterly devoid of acid properties. It is obtained by heating equal weights of Nitrate of Potassa and Sulphuric acid, $KO, NO_5 + 2(HO, SO_3) = KO, SO_3 + HO, SO_3 + HO, NO_5$.

We place, for example, the above materials in a glass retort, Fig. 134, and apply heat by means of a spirit lamp; then, as the Hydrated Nitric acid is liberated, it distils over into

Fig. 134.

the glass receiver, kept cool by a stream of water distributed on its surface by means of linen or soft paper.

Besides this compound, which has a specific gravity of 1.517, and which consists of 54 parts Anhydrous acid united with 9 parts water; another definite compound of the Anhydrous acid with water exists, which has a specific gravity of 1.424, and contains 54 parts of the former to 36 parts of the latter. Its formula would, therefore, be $4HO, NO_5$.

Properties. — The metals placed in contact with Nitric acid are oxidized at the expense of the acid, the latter easily yielding up a portion of its oxygen to them; and owing to this free liberation of oxygen combustible bodies, such as charcoal powder, oil of turpentine, sulphur and phosphorus, burn vividly when Nitric acid is dropped upon them. Its chief use, indeed, is as an *oxidizing* agent. Strangely enough, when diluted till its specific gravity is 1·25, it oxidizes the metals more rapidly than when concentrated. And the same is true with regard to its action upon animal and vegetable bodies, such as the skin, wool, feathers, and albuminous bodies, lignin, starch, and similar substances.

Uses. — Owing to the rapidity with which Nitric acid oxidizes the metals, and the great solubility of the nitrates in water, Nitric acid is of invaluable use in the laboratory for dissolving minerals, metals, etc. Used to oxidize SO_2 into SO_3 in the manufacture of sulphuric acid; when mixed with hydrochloric acid, as *aqua regia,* to dissolve gold, platinum, etc.; to convert starch and sugar into *oxalic acid;* in *dyeing;* in engraving on copper and steel—*etching;* in the *assay of money;* in polishing and cleaning rust from metals and alloys. It converts benzole into artificial *oil of bitter almonds;* it is employed in forming *aniline colors*, and to transform cotton fibre to gun-cotton.

Tests.—Bleaches a solution of Indigo in Sulphuric acid when boiled with that liquid. Gives a brownish-red color

in contact with a concentrated solution of Protosulphate of Iron.

Compounds of Nitrogen and Hydrogen.

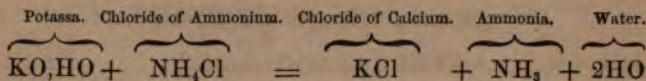Sym. NH_3.　　AMMONIA (Volatile Alkali).　　Eq. 17.

Sources.—When Nitrogen and Hydrogen come together in the *nascent state*, that is, at the moment when either one of them is liberated from some previous combination, they unite to form Ammonia. Thus, when lightning flashes through the air a small amount of vapor of water, HO, is decomposed into its two component elements, H and O. The hydrogen and oxygen, at the moment of their liberation, unite with the nitrogen of the atmosphere; the former to form Ammonia, NH_3; the latter, Nitric acid, NO_5. Or, when iron is exposed to the action of moist air, the iron decomposes the water, and unites with its oxygen, to form rust or Sesquioxide of iron (Fe_2O_3), while the Hydrogen set free, in the nascent state, combines with the nitrogen of the air to form Ammonia: $2Fe + 3HO + N = Fe_2O_3 + NH_3$. Ex. Disengagement of Ammonia from rust on mixing the latter with caustic potash.

In the same manner, when Nitric acid acts upon zinc, tin, and iron; thus, $8Zn + 8(HO,NO_5) = 8(ZnO,NO_5) + 8H$, the liberated hydrogen has the power, while in the nascent state, to decompose another portion of the Nitric acid, and form Ammonia: $HO,NO_5 + 8H = 6HO + NH_3$.

Lastly, when organic substances decompose — I. Spontaneously — II. By heat alone — III. By heating with caustic potassa — the nitrogen and hydrogen combine, in the nascent state, to form Ammonia, and in this way is derived *the fertilizing property of manure*, and the *ammoniacal liquor* of gas-works, which is the commercial source of Ammonia.

Preparation.—I. Fill a matrass half full of equal weight

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of caustic potash and sal ammoniac, and heat the mixture
gently ; collect over mercury, or by displacement upwards:

Potassa.   Chloride of Ammonium.   Chloride of Calcium.   Ammonia,   Water.

$$KO,HO + \quad NH_4Cl \quad = \quad KCl \quad + NH_3 + 2HO$$

II. A slight heat is sufficient to disengage all the Am-
monia from its solution in water—the liquid Ammonia of
commerce.

Liquid Ammonia is prepared by receiving the ammo-
niacal gas, first in a wash-bottle, filled with
milk of lime, which is merely the hydrate
of lime, CaO,HO, diffused through water,
in order to absorb the Carbonic acid and im-
purities accidentally present, and afterwards
in a series of Woulf's bottles, Fig. 135, filled
with distilled water. The gas enters by
tube A, bubbles through the water, and
passes by C into another similar bottle.
The tube D serves to prevent the liquid in
one bottle from being drawn into another in case of a sud-
den absorption, air instead then entering by this tube.

Fig. 135.

Properties.—Ammonia is a colorless gas, which may be
recognized : 1st, by its sharp, penetrating odor; 2nd, by
its power of bluing turmeric paper, turning a solution of
violets green, and cochineal, purple — whence its name of
volatile alkali; 3rd, by the white fumes or cloud of Chlo-
ride of Ammonium, NH_4Cl, which revolve about a glass
rod previously moistened with Hydrochloric acid, HCl,
when brought near the slightest trace of free ammonia.
It extinguishes a burning candle, but burns with a yellow
flame when introduced in a fine jet into a bell-glass filled
with oxygen ; it cannot be respired, and produces ophthal-
mia among workmen exposed to ammoniacal fumes.
Dropped on the skin, liquid ammonia produces a blister,
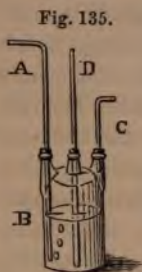
and it is consequently employed to cauterize the bites of mad dogs. It is decomposed by heat and electricity into nitrogen and hydrogen; by oxygen, with the aid of electricity, into water and nitrogen; a few bubbles of chlorine passed into a receiver filled with ammoniacal gas produce chloride of ammonium and nitrogen, accompanied by heat and light.

Uses.—Equal amounts of cochineal, ammonia, and water boiled together furnish *carmine.* Many colors may be made, and still others, such as crimson and Prussian blue, may be modified by ammonia. It is largely employed by scourers to take out grease spots, and to restore colors changed by acids; by the manufacturers of artificial pearls to prepare the *Essence d'Orient.* This is obtained by holding in suspension in liquid Ammonia the minute scales of the *Blay-fish*, and is used by injecting it into pearl-like globules of glass. The scales attach themselves to the inside walls of the hollow glass drops, and sparkle like Indian pearls.

In *medicine*, besides its internal and external application to the bites of serpents, stings of insects, etc., it is used in the treatment of *hoven.* This disease arises in sheep and cows from eating green apples and wet grass, which generate so large a quantity of Carbonic acid in the intestines, as to cause death in a short time. The ammonia absorbs this gas, forming the salt, Carbonate of Ammonia.

Sym. Cl.   **CHLORINE.**   Eq. 35.5.

Discovered by Scheele in 1744. Its true character pointed out by Gay Lussac and Thenard in 1809. Its name given by Sir H. Davy, from χλωρός, yellowish-green, color of young grass. Chief source in nature, common salt.

Preparation. — 1st. Heating in a flask *slightly diluted* hydrochloric acid with binoxide of manganese, $2HCl +$

$MnO_2 = MnCl + 2HO + Cl$ (Fig. 136); 2nd. Heating common Salt, Binoxide of Manganese and Sulphuric acid, $NaCl + MnO_2 + 2(HO,SO_3) = Cl + NaO,SO_3 + MnO,SO_3 + 2HO$. Best collected by displacement, as Fig. 136, or if

Fig. 136.

for any reason over water cold water is better than hot, care being taken to let it *pass through* as little as possible.

Properties. — Chlorine is a gas of a greenish-yellow color, an acrid taste and disgusting suffocating smell. It becomes liquid under a pressure of 4·5 atmospheres at 60°.

This gas has a strong affinity for the metals, so that many of them will inflame if thrown into it. Thus, for example, is it with Antimony, Arsenic, Potassium, etc., in powder, or Dutch gold leaf (made of brass). (Fig. 137.) Its affinity for Hydrogen is also very great; mingled with that body it will combine slowly in diffused light, but explosively in the direct rays of the sun, electric lamp, etc. To this attraction it owes its efficiency as a bleaching agent. By combining with and removing the Hydrogen from organic coloring matter it destroys it, and thus bleaches or removes all such substances.

Bleaching.—In practice, goods to be bleached are first well washed and boiled in water with strong alkalies, to remove all grease, etc.; then they are saturated with chloride of lime mixed in water; then they are immersed in water containing a little sulphuric acid, which liberates chlorine from the chloride of lime contained in the cloth among its fibres. This effects the bleaching most perfectly.   The cloths must lastly be washed for a long time in fresh water, to remove all trace of acid.   To remove stains from linen or cotton goods, in the small way, Chloride of Soda (Labarraque's Solution) or Chloride of Potash (Javelle water) which may be obtained from any apothecary, are very useful. The stained cloth should be immersed in the solution; a little boiling water added, if necessary, or, in obstinate cases, the whole placed in the sun for some hours. The article should be thoroughly rinsed with fresh water before it is allowed to dry. Colored fabrics cannot be thus treated, as their color would disappear with the stain.

Fig. 137.

Woollen cloths are not bleached with chlorine, but with fumes of burning sulphur, i. e. Sulphurous acid, SO_2.

It is by an action similar to the above that Chlorine acts as a deodorizer, breaking up the offensive gases by removing their hydrogen or like element. A little chloride of lime thrown under a floor will thus afford entire relief from the "attacks" of a dead mouse.

Test —We recognize free Chlorine by its smell, color,

heavy fume with ammonia, curdy white precipitate with nitrate of silver, and bleaching of organic colors.

Compounds of Chlorine and Oxygen.

Hypochlorous Acid—ClO. An orange-yellow liquid, obtained by passing Chlorine over red Oxide of Mercury, $2HgO + 2Cl = HgCl,HgO + ClO$. Readily decomposed by heat into oxygen and chlorine. It bleaches powerfully, and combines with the alkalies to form hypochlorites, possessing the same property.

Chlorous Acid—ClO_2. A greenish-yellow gas, obtained by heating a mixture of Arsenious acid, Chlorate of Potassa, and Nitric acid. The nitric acid yields up some of its oxygen to the arsenious acid; nitrous acid is formed, and afterwards converted back again into nitric acid by oxygen given off from the decomposed chloric acid. Thus $AsO_3 + HO,NO_5 = AsO_5 + HO,NO_3$; and $HO,NO_3 + KO,ClO_5 = KO,NO_5 + ClO_3 + HO$.

Hypochloric Acid—ClO_4. A deep-yellow explosive gas, evolved by heating concentrated Sulphuric acid with Chlorate of potassa, $3(KO,ClO_5) + 3(HO,SO_3) = 2ClO_4 + ClO_7 + 3(KO,SO_3) + 3HO$.

Chloric Acid—ClO_5. Obtained by boiling Chlorate of Potassa with Hydrofluosilicic acid.

Test.—The chlorates evolve pure oxygen when heated.

Perchloric Acid—ClO_7. Shown above as one of the products in formation of Hypochloric acid.

Compounds of Chlorine with Hydrogen.

Hydrochloric Acid—HCl.

Preparation.— 1st. When equal volumes of Hydrogen and Chlorine are exposed to the direct sun-light they unite explosively. 2nd. From Sulphuric acid and common Salt. $NaCl + HO,SO_3 = NaO,SO_3 + HCl$.

Properties.—A powerfully acid gas, with an intense at-

traction for water. The latter absorbs 418 times its bulk of this gas to form the liquid known as Hydrochloric acid. Unites with metals, forming chlorides, with liberation of hydrogen, and with metallic oxides, to form chlorides and water.

Uses.—It is a very delicate test for the salts of silver and for ammonia. It is employed in the arts for preparing *Labarraque's solution, Javelle water, bleaching powder,* for the extraction of gelatine from bones, etc. It is used alone, or in aqua regia, to dissolve very many minerals, and to prepare the metallic chlorides.

Chloride of Nitrogen—NCl_3. A fearfully explosive oily liquid, formed by passing chlorine into a solution of sal ammoniac.

Sym. Br. **BROMINE.** Eq. 78.26.

Discovered by M. Balard in 1826. Named from βρῶμος, a disgusting smell. Found in sea-water, especially of the Dead Sea, mineral springs, and native bromides. Sp. Gr. 2.96.

Preparation.—Bittern, which is the mother-liquor of sea-water, after the less soluble salts have been separated by crystallization, contains various bromides. These are decomposed by a stream of chlorine passed through the liquid, and the bromine, set free, dissolves in a quantity of ether agitated with the bittern thus treated.

Properties.—When separated by a complicated process from the ether, Bromine is a deep-red, volatile liquid, of a very suffocating and offensive odor; freezes at about 19° and boils at 145°; bleaches many vegetable colors; unites directly with many of the metals, sometimes with ignition, forming bromides. Bromide of silver is considerably employed in photography. Combines with Hydrogen to form Hydrobromic acid, HBr.

Test. — Starch is colored yellow by free bromine.

Sym. I.   **IODINE.**   Eq. 126.36.

Discovered in 1812 by M. Courtois. Named from ἰώδης, violet-like. Found in sea-water, sea-weeds, some mineral springs, and as iodides of lead and silver. Sp. Gr. 4.94.

Preparation.—By gently heating the bittern from kelp, which contains Iodides of Sodium, Magnesium, etc., with Sulphuric acid and Binoxide of Manganese. Thus, $KI + MnO_2 + 2 (HO,SO_3) = I + KO,SO_3 + MnO,SO_3 + 2HO$.

Properties.—At ordinary temperatures a metallic bluish-black solid, having the form of rhomboidal scales or tapering octahedrons; at 225° it changes to a liquid, and at 347° to a rich intense violet vapor. It is but slightly soluble in water, which dissolves about 0.007 of its weight at ordinary temperatures; in ether and alcohol it dissolves readily and forms dark reddish-brown liquids. Its chemical affinities are like those of chlorine and bromine, but being more feeble it is displaced from combination by these two metalloids. It unites with hydrogen to form *Hydriodic acid*, HI, and with oxygen to form *Iodic acid*, IO_5, and *Periodic acid*, IO_7, but none of these compounds are of practical importance.

Test.—It unites with starch, in the presence of water, to form a beautiful blue *iodide of starch*. This iodide loses its color at a temperature of 165°, and recovers it again on allowing the liquid to cool.

Uses.—Iodine alone, or in combination with potassium, is a remedial agent for goitres and scrofula. The iodides of potassium, sodium, ammonium, and cadmium are employed in photography to iodize the collodion.

Sym. F.   **FLUORINE.**   Eq. 18.7.

Discovered by Sir. H. Davy, but has never as yet been isolated in such a state as to admit of satisfactory inves-

tigation. It derives its name from fluor spar, in which it is chiefly found; specific gravity, 1.32 (theoretical).

Hydrofluoric Acid—HF. A highly acid gas obtained by acting on fluor spar (fluoride of calcium) with Sulphuric acid, $CaF + HO,SO_3 = CaO,SO_3 + HF$.

Use.—It acts powerfully on all siliceous matters, and is therefore employed in etching glass. For this purpose the plate, or other object to be etched, is coated with wax; the design to be produced is scratched through this. Some Fluor spar in coarse powder is then spread in a shallow leaden dish (see Fig. 138), moistened with oil of vitriol *warmed* with a spirit lamp. As soon as fumes comes off the *lamp is removed*, and the plate set face downwards for a minute or two upon the dish. The exposed parts of the

Fig. 138.

glass are corroded by the fumes and acquire the appearance of ground glass, thus showing the design upon the smooth glass when the wax has been removed by scraping and rubbing with turpentine. Thermometer tubes, chemical bottles, etc., are often marked in this way. Plates of glass on which frost-like crystals have been formed, by spreading them with gum-water containing in solution, Nitre, Sulphate of Copper, or the like, may be thus etched so as to form beautiful objects for the magic lantern, or glass goblets may be permanently frosted by this process. A solution of HF in water etches likewise, but with a smooth surface.

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Sym. C.   **CARBON.**   Eq. 6.

Carbon occurs in three forms:

1st. **Diamond**, whose name is a corruption of *adamant* (from α, privative; and δαμάω, *I subdue*), invincible. Hardest of all substances, cannot be cut except by its own dust; but scratches all other minerals and metals. Sometimes colored, but usually limpid; infusible at all temperatures; combustible at a white heat with formation of Carbonic acid gas; of a high refractive and dispersive power; feebly phosphorescent when brought into a dark room after exposure to light. It crystallizes in octahedra and tetrahedra, oftentimes with curved faces. It is probably of vegetable origin.

Uses. — As an ornament, cut as a *rose* or *brilliant;* the former having the under surface flat, and the upper elevated, *en dome*, without table, and reflecting light from 24 facets; *the brilliant* is cut into symmetrical facets on both lower and upper faces. 2nd. For cutting glass, for delicate pivot-rests, and as a grinding and polishing powder.

2nd. **Graphite** or **Plumbago.**—A very friable substance, soft and greasy to the touch, and of a metallic leaden-gray lustre. It is largely worked at Ticonderoga, New York, and at Brandon, Vermont. It is sometimes found in brilliant six-sided spangles, which may also be artificially produced by dissolving charcoal in melted iron.

Uses.—Lead-pencils; mixed with fire-clay, it is made into "black-lead" crucibles for melting gold, silver, etc.; it is rubbed over iron-castings to preserve them from rust — *stove-polish;* to relieve the friction of carriage axles, wheels of machinery, and even of clocks; to polish gun-bullets; smeared over the wax medals in an electro-plating bath to cause the deposition of gold and silver upon their surface.

3rd. **Amorphous Carbon.** — In consequence of its infusibility carbon presents itself in a variety of aspects according to the structure of the body from which it was formed and the manner of its preparation, viz. :

(*a*) *Metallic Carbon.* — A metallic coating formed by the contact of the carburetted hydrogen gases produced in the distillation of coal with the red-hot sides of the retort. It is an excellent material for the carbon points of the electric light, and for the positive pole of Bunsen's battery.

(*b*) *Charcoal* is formed by burning stacks of wood which are covered over with leaves and dirt to prevent a free access of air. The charcoal of light woods, such as black alder and willow, is largely consumed in gunpowder. As a powder, charcoal is used for polishing copper and bronze; as a dust, it is sprinkled over meats to preserve them from decay ; in lumps, to absorb noxious gases. So the charring of the ground end of fence posts secures them from rot.

(*c*) *Coke* is obtained by distilling off the water, tar, and gas from bituminous coal ; 100 tons of the latter affording 50 or 60 tons of coke. It produces a greater heat than any other fuel, except Anthracite, and is largely employed in blast furnaces, forges, etc.

(*d*) *Lampblack* is condensed upon the sides of chambers, in which resins, fats, etc., are burnt with an insufficient draft of air. It is employed in painting; mingled with two-thirds its weight of clay, to form black drawing-crayons ; intimately mixed with dry linseed-oil to make an indelible printer's ink. Manuscripts, written in an ink composed of lampblack and gum-water, have been exhumed at Herculaneum and Pompeii, still perfectly legible.

(*e*) *Animal charcoal* is made by burning bones in close vessels. It serves as an antidote to vegetable and animal poisons, but its principal use is to refine sugar. After a while it loses its power of decolorizing syrup ; but it may

be revivified by drying, saturating with Hydrochloric acid gas, washing, and reburning. (See Franklin Institute Journal, V. 49, p. 250.)   Ex. A rich solution of indigo, filtered through animal charcoal, loses its color entirely.

Compounds with Oxygen.

Carbonic Oxide—CO.   Sp. Gr. 0.972.

Preparation.—Heat 1 part of Ferrocyanide of Potassium with 10 parts of sulphuric acid. $K_2C_6N_3Fe + 6(HO, SO_3) + 6HO = 6CO + 2(KO,SO_2) + FeO,SO_3 + 3(NH_4O, SO_3)$

Properties.—A colorless, inodorous, poisonous gas; extinguishes flame, but burns itself with a purplish blue flame, easily extinguished.   Seen in coal fires where there is a lack of air.

Carbonic Acid—CO_2. (Fixed air, choke-damp.) Sp. Gr. 1.527.

Sources.—Combined with lime, as limestone, forms one-seventh of the solid crust of the earth's surface.   United with iron, copper, zinc, etc., forms many valuable ores. Constitutes one-thousandth part of our atmosphere.

Preparation. — By decomposing a carbonate by any strong acid.   Ex. $NaO,CO_2 + HO,SO_3 = NaO,SO_3 + HO + CO_2$.

Thus we place in a vessel such as A (Fig. 139) some common washing soda (Carbonate of Soda), and pour upon it dilute Sulphuric acid.   The gas is then freely developed, and may be collected by displacement.   This gas is also produced in all ordinary cases of combustion and in respiration.   The amount of CO_2 exhaled by a man in twenty-four hours, is about $26\frac{1}{2}$ ounces.   This would give for the inhabitants of the world, about 820,000 tons per day.   Fortunately, plants reverse this action.

Properties.—The weight of this gas is very notable.   It may be poured from one vessel to another and weighed

readily on a large scale in a grocer's paper-bag, or in a wooden bucket.

Many of its properties may be well exhibited by arranging an artificial grotto, Fig. 139, and allowing the gas

Fig. 139.

from the bottle, A, to flow into it.   This will settle like water at the lower part, and a taper will burn within until lowered beneath the surface of the gas. A little slide being then opened in the side of the box, the gas may be drawn off into vessels, poured from them over candles so as to extinguish them, etc.

It directly interferes with and prevents combustion.   It has therefore been used, by Sir Goldsworthy Gurney, in fire-engines which pour Carbonic acid instead of water upon a burning building, and for putting out fires in burning mines. Does not support respiration ; and when formed in mines by explosions of fire-damp, it is the *choke-damp* so fatal to miners.   Under the influence of light, it is decomposed in the leaves of plants.   The carbon being essential to vegetable growth, is retained by the plant; while the oxygen is returned to the atmosphere, in order that animal life may be sustained.   It is soluble in water, and when held in solution under pressure, makes soda-water.

Liquid Carbonic Acid.—Under a pressure of 40 atmos-
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pheres, or 600 lbs. to the square inch, Carbonic acid gas is condensed to a colorless liquid.

Solid Carbonic Acid.—When a jet of this liquid is thrown into a metallic receiver filled with holes, the vessel is seen to fill rapidly with a flaky snow. This is solid Carbonic acid, formed by the great cold—about 150°—given out in the very rapid evaporation of part of the liquid Carbonic acid. By mixing solid Carbonic acid with ether, and evaporating under the receiver of an air-pump, a temperature as low as–166° F. is produced. This mixture, as it were, *burns* the hand if placed upon it, and causes active inflammation.

Test.—Lime-water is so delicate a test that it is rendered cloudy by blowing the air from the lungs through it for a very short time.

Compounds of Carbon with Hydrogen.

Protocarburetted Hydrogen — C_2H_4. (Light Carburetted Hydrogen). Exists native, as fire-damp in coalmines, and the inflammable air of marshes—marsh-gas. Prepared by heating 4 parts of acetate of soda (which must be first dried), 4 parts of caustic potash, and 6 parts quicklime, powdered and mixed in a strong glass flask, $2(NaO,C_4H_3O_3) + KO,HO + CaO,HO = 2(NaO,CO_2) + KO, CO_2 + CaO, CO_2 + 2 C_2 H_4.$

Properties.—A colorless, transparent gas. Sp. Gr. 0.555. -Extinguishes flame, but burns itself with a pale yellow flame; mixed with air and lighted, explodes.

Bicarburetted Hydrogen — C_4H_4. Sp. Gr. 0.98. Also called Heavy Carburetted Hydrogen and Olefiant Gas.

Preparation.—One measure of alcohol is heated with 3 of sulphuric acid, $C_4H_6O_2+2(HO,SO_3)=2(HO,SO_3)+2HO + C_4H_4.$ To avoid frothing, we pour sand into the flask till all the liquid is absorbed by it.

*Properties.* — A colorless gas, with a sweet, alliaceous

odor; soluble in about 12 times its bulk of cold water; liquefiable under great pressure; not a supporter of combustion. Very inflammable, burning with a white luminous flame. Combines with chlorine to form Dutch Liquid, $C_4H_4Cl_2$.

Remark.—The two preceding gases are the principal constituents of coal-gas. Prepared by distilling bituminous coal in large iron retorts; purifying the gases evolved by passing it through vessels filled with spray of water (which absorbs their ammoniacal impurities),

Fig. 140.

Fig. 141.
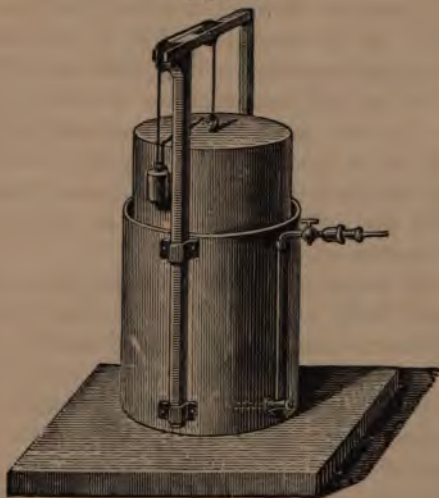
and through vessels containing moist lime (which absorbs the sulphur and carbon compounds), and lastly, storing them in large, self-adjusting gas holders; whose principle is illustrated by the smaller apparatus figured in the cuts. Fig. 140, and Fig. 141. As the gas flows in, the inner drum rises, giving space; as it escapes, this sinks, so diminishing the capacity of the vessel.

Compound of Carbon with Nitrogen.

Cyanogen—C_2N or Cy.   Sp. Gr. 1.82.

Source. — Cyanogen is formed, in combination with potassium, by heating organic substances containing nitrogen, such as fibrine, gelatine, skins, etc., with potash.

Preparation.—Obtained by heating Cyanide of Mercury. $HgC_2N = Hg + C_2N$.

Properties.—A colorless, soluble gas; liquefiable by a pressure of four atmospheres. Its odor resembles that from bitter almonds. Burns with a dark blue flame fringed with purple. In chemical properties, it must be classed with chlorine and bromine ; uniting, like them, with hydrogen to form an acid, and with the metals to form salts. It was the first one, among many compound bodies since discovered, which was found to play the part of an element ; and the discovery of this " Compound Radical," as such bodies are called, by Gay Lussac, in 1814, greatly simplified modern chemistry.

Uses.—Its combination with hydrogen, *Hydrocyanic,* or *Prussic* acid, HCy, is a fearful poison, whose proper antidote is chlorine or ammonia, cautiously inhaled. Diluted, however, with 50 times its weight of water, it is employed to allay nausea, and as a lotion in skin diseases. Cyanide of Potassium, KCy, energetically dissolves the cyanides of gold and silver, and forms with them double cyanides, which constitute the gold and silver baths in Electro-

plating. Alone, Cyanide of Potassium is excellent for fixing Collodion Positives.

Compound of Carbon with Sulphur.

Bisulphide of Carbon—CS_2, Sulphocarbonic Acid. Sp. Gr. 1.272.

Preparation.—Prepared by passing sulphur vapor over ignited charcoal and condensing the result by cold. A transparent, colorless liquid, insoluble in water, of most disgusting smell.

Uses.—To dissolve sulphur, phosphorus, many resins, oils, etc. Owing to its great refracting and dispersive power, it is employed in prisms of the spectroscope and other optical instruments; in the construction of thermometers for measuring intense cold, since it cannot be frozen; along with tallow and phosphorus, as a substitute for black-lead in electro-silvering large medals, etc. To remove grease-stains.

Sym. B. **BORON.** Eq. 1.09.

Discovered by Davy, 1807.

Preparation.—The double fluoride of boron and potassium is heated with an equal weight of potassium. $KF,BF_3 + 3K = 4KF + B$.

Modifications. — 1st. As thus obtained, Boron is an amorphous olive-green powder, which burns when heated in the air to a point below redness, forming Boracic acid. In this condition it corresponds to charcoal.

2nd. As octahedra; which are very hard, highly refracting; fusible only under intense heat, and in all respects like Diamond.

3rd. As scaly, hexagonal plates, resembling Graphite.

Compound with Oxygen.

Boracic Acid—BO_3. Sp. Gr. 1.8.

Source.—Discharged from small craters or *soffioni*

along with sulphuretted hydrogen and steam, into the bottom of the Tuscan *lagunes*. The waters of these lagunes are evaporated until the Boracic acid which they hold in solution crystallizes out. The requisite heat is derived from the vapors of the soffioni, which are conducted by stone passages beneath the evaporating pans.

Preparation.—Decomposing Biborate of Soda with Sulphuric acid, $NaO,2BO_3 + HO,SO_3 + Aq = NaO,SO_3 + 2BO_3 + HO + Aq$.

Properties.—It contains 3 equivalents of water of crystallization, separable from the acid at a red heat; tinges flames green, and combines with bases to form borates, the most important of which is biborate of soda or *borax*. The latter is also imported largely from Thibet, under the name of *tincal*.

Uses.—Borax is employed in medicine, enters into the composition of a glaze for stoneware, is used as a flux in blowpipe analysis, and in welding and soldering.

Sym. Si.   **SILICON.**   Eq. 21.35.

Discovered by Berzelius, 1824.

Source.—Exists in three forms, like Carbon and Boron: (*a*) As obtained in the above reaction, a dark-brown powder, burning, when heated in the air, to Silicic acid, SiO_3. (*b*) Resembling diamond. (*c*) Graphitoidal.

Preparation. — Prepared like Boron: $KF,SiF_3 + 3K = 4KF + Si$.

Compound with Oxygen.

Silicic Acid, Silex, Silica, SiO_3.   Sp. Gr. 2.66.

Source. — Forms 45 per cent. of the solid crust of the globe, occurring pure as *quartz* (rock crystal); almost pure in *chalcedony*, *flint*, *agate*, and *carnelian;* chief ingredient of sandstone rock.   Combined as a mineral acid with almost every known base, it forms a vast variety of ores

and rocks. It is found in small quantities in the ashes of nearly all vegetables.

Preparation. — The process consists of two parts: (*a*) equal quantities of powdered glass and fluor spar are heated with sulphuric acid; the hydrofluoric acid generated from the fluoride of calcium and sulphuric acid decomposes the silicic acid in glass, forming gaseous *terfluoride of silicon*, SiF_3; (*b*) This gas is made to bubble through a large amount of water in another vessel; the water is decomposed by it, and hydrofluosilicic acid, $3HF,2SiF_3$, together with gelatinous silica is formed; thus, (*a*) $9CaF + 9HO,SO_3 = 9HF + 9CaO,SO_3$, and $9HF + 3SiO_3 = 9HO + 3SiF_3$. (*b*) $3SiF_3 + 3HO = SiO_3 + 3HF,2SiF_3$.

Properties.—(*a*) *Physical.* Anhydrous Silicic acid is a snowy-white, tasteless *solid*, infusible in the fiercest blast of a furnace, but can be spun out before the oxyhydrogen blow-pipe into very fine threads.

(*b*) *Chemical.* Silicic acid exists in two entirely different forms : —

1st. *Insoluble Silica.* Anhydrous Silicic acid, after having been heated to redness, is insoluble in water and all acids, except hydrofluoric. Fused with the alkalies or their carbonates, it is converted into

2nd. *Soluble Silica.* In this way the chemist is able to attack and dissolve with acids a great number of siliceous minerals.

Though Silica is a very feeble acid, yet when heated with compounds of the strongest acids, as the sulphates, it can expel them on account of its non-volatility, or fixedness.

Varieties. — Crystallized in ice-like hexagonal prisms, it is known as *rock crystal;* stained by nickel an apple-green, *chrysoprase;* by sesquioxide of iron, clear yellow and bright red, *false topaz* and *carnelian;* by sesquioxide of manganese, violet, *amethyst.* When the color is centred

in blood-red spots, it is known as *blood-stone*, when grouped
in concentric layers of varying tint, as *sardonyx*, *Mocha
stone*, *riband jasper*, and the *Lydian* or *touch-stone*.
When the Silica occurs as a hydrate, and sends from its
interior broken beams of light, hyacinth red, and golden
and fiery crimson, it is called *girasol* and *noble opal*.

Uses.—As a jewel; in irregular conchoidal masses, *gun-
flints;* as *agate* rests for the knife-blades of delicate
balances; as *tripoli* — a granular Silicic acid, the remains
of shell-fish—for polishing. In the form of grain or sand,
in all glass-making and pottery; as sand compacted by a
natural cement of lime or silica, an invaluable building
material — *sandstone*, etc.

———

Sym. S.   **SULPHUR.**   **Eq. 16.**

Sources.—Found native in the volcanic districts border-
ing upon the Mediterranean, especially at the Solfatara
near Naples, and at Mt. Etna; in South America, India,
and the volcanic islands of the Pacific. Many valuable
ores are sulphides, such as *cinnabar, smaltine, kupfer-
nickel, pyrites,* and *blende;* and as a sulphate, in *gypsum,
heavy spar,* and *celestine,* it no less abounds. In combi-
nation with hydrogen, it gives to many mineral waters
their offensive smell and taste; it is present in *oil of mus-
tard, garlic, assafœtida,* and *onions;* and accompanies the
petroleum which flows from Canadian wells.

Preparation. — Purified from the blue clay, gypsum, or
rock salt, in which it is found, by sublimation. It is *di-
morphous,* and has

Modifications.—1st. As found native, or as obtained by
evaporating a solution of Sulphur in Bisulphide of Carbon,
it is a semitransparent, amber yellow, rhombic *octahedron*
In this, which is its stable form, it has a sp. gr. 2.05, and
fuses at 239°.

2nd. Crystallizes from fusion in transparent, brownish-yellow, oblique rhombic *prisms;* sp. gr. 1.98; fuses at 248°. Unstable, shortly becomes opaque, and crumbles into the first form.

3rd. Heated above 482°, and suddenly cooled, assumes the condition of an amber-colored elastic solid. But even its *amorphous* form is unstable, and after a while becomes brittle by crystallizing into octahedra. A red and black modification likewise exist.

Properties.—Burns at 460°, and forms Sulphurous acid; sublimes into *flowers;* when heated and run into moulds forms *Roll-sulphur* or brimstone. Combines readily with Chlorine, Bromine, and Iodine; has such an affinity for metals that many of them, in powder, will burn vividly, if heated in its vapor, and form sulphides or sulphurets.

Uses.—It is applied in taking impressions, and in making moulds or medals; in *vulcanizing* India-rubber; for matches; constitutes 10 per cent. of gunpowder. It was selected as a lubricant for the axles of the car on which the monster Fort Pitt cannon was transported from Pittsburg to Philadelphia. It is prescribed for constipation, gout, asthma, etc.; externally as an ointment for cutaneous diseases, and both internally and externally for chronic rheumatism.

Compounds with Oxygen.

Sulphurous Acid—SO_2. Sp. Gr. 2.247.

Preparation. — By burning Sulphur in Oxygen, or by heating Sulphuric acid with copper, $Cu + 2(HO,SO_3) = CuO,SO_3 + SO_2 + 2HO$.

Properties. — A suffocating, irrespirable gas; becomes liquid at 14°; water absorbs 44 times its bulk of this gas, which must therefore be collected over mercury. May be combined with many bases by being transmitted through water holding the metallic oxide or carbonate.

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Uses — Owing to the property which Sulphurous acid possesses of bleaching most coloring matters, it is largely employed to whiten silk and wool. Chlorine cannot be employed to bleach these two fabrics, because it tinges them yellow. The moistened goods are simply thrown over rails in large rooms, where Sulphur is kept burning. To bleach isinglass (gelatin) and the straw for bonnets, hats, etc.; to take out fruit-stains from pocket-handkerchiefs, dresses, etc.; to free infected places from miasma and infection, and to purify lazarettos. In casks, it prevents the wine they contain from turning into vinegar: it is sufficient to burn in them a little sulphur. Sulphurous acid in combination with Soda, as Sulphite of Soda, NaO, SO_2, is employed, under the name of *antichlorine*, to combine with the excess of chlorine, or hypochlorite of lime, which has been used in bleaching paper-pulp, and, by neutralizing it, prevent the evil effects which would ensue from an overdose of chlorine.

Sulphuric Acid — SO_3. Distils over from fuming Nordhausen acid as a white, silky solid, devoid of acid properties, $HO,2SO_3 = HO + 2SO_3$. Possesses an intense affinity for water, and when combined with it as a hydrate forms what is generally known as concentrated oil of vitriol, or Sulphuric acid, HO,SO_3. Sp. Gr. 1.84; melts at 65°. There are four hydrates.

1. *Dihydrate* — $HO,2SO_3$. Nordhausen Sulphuric acid, formed by distilling dried sulphate of iron.

2. *Monohydrate* — HO,SO_3. Formed by concentrating in platinum stills the weak brown acid (see next page). An intensely acrid, powerful acid; destroys organic substances by its strong attraction for the elements of water; for the same reason very valuable as a desiccating agent. Sp. Gr. 1.845. Freezes at —30; boils at 640°.

3. *Bihydrate* — $2HO,SO_3$. Obtained when sufficient water has been added to the Monohydrate to reduce its

density to 1.78. Crystallizes in beautiful rhombic prisms at 47°; boils at 435°.

4. *Terhydrate*—$3HO,SO_3$. By evaporating at 212° in vacuum a still more dilute acid till it ceases to lose weight. Sp. Gr. 1.63; boils at 348°.

*Preparation.*—*Process of the Leaden Chambers.* Consists in, 1st. A deoxidation of Nitric acid by Sulphurous acid, $SO_2 + HO,NO_5 = HO,SO_3 + NO_4$. 2d. A union of the Hyponitric acid so formed with 2 equivalents of sulphurous acid and an indefinite quantity of water, to form a thick crystalline compound (NO_4+2SO_2+Aqua). 3d. An immediate decomposition of this compound in contact with steam, and the formation of 2 equivalents of sulphuric acid, which remain in solution, and 1 equivalent of Binoxide of Nitrogen; thus, $NO_4 + 2SO_2+Aq.=NO_2 +2(HO,SO_3) + aq.$ 4th. A union of this NO_2 with 2O to form NO_4 again. The NO_4 so formed repeats the second step; more NO_2 is formed, and so the operation continues by the carrying, on the part of the Binoxide of Nitrogen, of Oxygen to the Sulphurous acid.

The very dilute acid so formed is concentrated to a density of 1.72 by evaporation in leaden pans, and called Brown acid; and by further concentration in vessels of platinum becomes *oil of vitriol* of commerce, whose density should be 1.845.

We can demonstrate this action on the small scale very completely with the apparatus shown in Fig. 142. Into the large glass vessel, F, we pass Sulphurous acid from the flask, A, and Nitric oxide (which, with the air present, at once forms NO_4) from the gas-bottle, B. The reaction soon commences, and F becomes coated with silky crystals. We then pass in steam from C, when these crystals are decomposed, and red fumes reappear; then more Sulphurous acid from A is admitted, and air is forced in through D, while excess of gas escapes by tube E, leading to a chimney.

Uses.—In the manufacture of Carbonates of Soda, Nitric and Hydrochloric acids, Chlorine, Phosphorus, Alum, Copperas, Ether, and many other chemicals; in making candles, in refining coal-oil, etc.

Fig. 142.
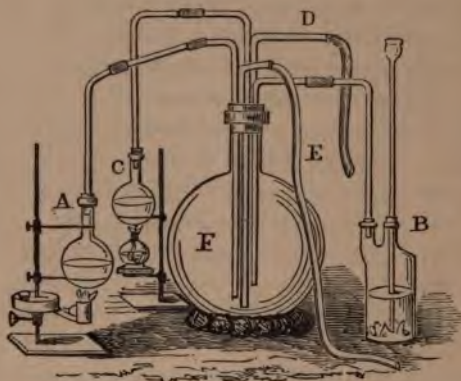
Test. — Gives a white precipitate with Chloride of Barium, $BaCl + HO,SO_3 = BaO,SO_3 + HCl$.

Other Compounds of Sulphur and Oxygen,

Not important, except Hyposulphurous acid, S_2O_2. This is employed in combination with soda, as Hyposulphite of Soda (NaO,S_2O_2), to *fix* the photographic image; that is, to decompose the Chloride of Silver which has not been affected by the light while in the camera, and which if allowed to remain on the paper, after removal from the camera, would darken and obliterate the picture. The result of this decomposition is Hyposulphite of Silver and Chloride of Sodium, both of which, unlike Chloride of Silver, are soluble in water, and may be washed off; thus, $NaO.S_2O_2 + AgCl = AgO,S_2O_2 + NaCl$. The Hyposul-

phites of Silver, Gold, and Platinum have not succeeded well as electro-plating baths for deposition of their respective metals.

Compound with Hydrogen.

Hydrosulphuric Acid — HS. Sulphuretted Hydrogen Sp. Gr. 1.17.

Preparation.—By reaction of diluted Sulphuric acid on Sulphide of Iron, $FeS + HO,SO_3 = FeO,SO_3 + HS$, or of Hydrochloric, acid on Tersulphide of Antimony, $SbS_3 + 3HCl = SbCl + 3HS$. The Sulphide of Iron may be placed in a flask like Fig. 143, and dilute acid introduced by the tube, as required to evolve the gas. Emitted from organic matters containing Sulphur, from drains, sinks, etc. It is this gas which blackens spoons employed in eating eggs, by forming on their surface black Sulphide of Silver, AgS.

Fig. 143.

Properties.—A colorless gas, smelling like rotten eggs; liquefied under 17 atmospheres; poisonous; burns with a pale-blue flame, forming water and Sulphurous acid; instantly decomposed by chlorine, owing to its superior affinity for Hydrogen.

Test. — A black precipitate with Acetate of Lead, $PbO,C_4H_3O_3 + HS = HO,C_4H_3O_3 + PbS$.

Uses. — Since it precipitates many of the metals from their acid solutions, by forming with them differently colored Sulphides, insoluble in water or acids, it is incessantly used in the laboratory to recognize the various metals, and separate them from each other. Sulphur baths, or those

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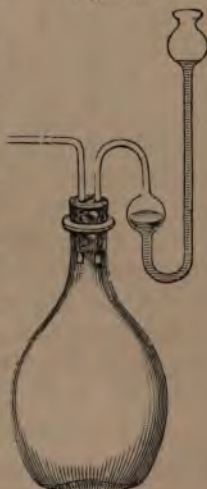
containing sulphuretted hydrogen dissolved in water, are prescribed for cutaneous diseases.

Sym. Se.   **SELENIUM.**   Eq. 39.28.

Discovered by Berzelius, 1817.   Sp. Gr. 4.5.

Sources. — Found combined with certain metallic sulphides; very rarely as Selenides.   Obtained by a complicated treatment of a red deposit formed in the works at Fahlun, where sulphuric acid is made from pyrites containing Selenium.

Properties. — As thus obtained Selenium is a reddish-brown, semimetallic-looking, amorphous solid; sp. gr. 4.3.; fuses at 220°, and evolves when heated a disgusting smell. It resembles sulphur very closely, existing in three corresponding modifications: 1st, amorphous, which has just been described; 2d, vitreous; 3d, as crystallized from solution in Bisulphide of carbon, rhomboidal prisms.   Its compounds with Hydrogen and Oxygen are analogous to those which sulphur forms with the same elements, viz., Hydroselenic acid, HSe; Selenous acid, SeO_2; and Selenic Acid, SeO_3; and, like sulphur, it combines directly with Chlorine and Iodine.

Sym. P.   **PHOSPHORUS.**   Eq. 32.

Named from φῶς, light; and φορὸς, carrying.   First obtained by Brandt, of Hamburg, in 1660.   Found as a phosphate of lime in many rocks.   By their decomposition phosphate of lime passes into the soil, from thence into many plants, and finally into the bones of animals, forming their chief earthy constituent; phosphorus seems essential to the brain and nerve tissue, and is an ingredient of albumen and fibrin.

Preparation. — When bones are burned, they are converted into a tribasic phosphate of lime, $3CaO, PO_5$.   If

this be treated with Sulphuric acid, Superphosphate of lime is formed; thus, $3CaO,PO_5 + 2(HO,SO_3) = 2HO,CaO,PO_5 + 2(CaO,SO_3)$. The acid solution is filtered from the insoluble sulphate of lime, evaporated to a syrup, and then heated to redness, with one-fourth its weight of charcoal. The superphosphate of lime is first decomposed into bone-ash and tribasic phosphoric acid, $3(2HO,CaO,PO_5)=3CaO,PO_5+2(3HO,PO_5)$; afterwards the hydrated phosphoric acid so formed is deoxidized by the charcoal, $2(3HO,PO_5)+16C=2P+6H+16CO$.

Properties. — A semi-transparent, colorless, wax-like solid, which emits white alliaceous fumes in the air. Has a sp. gr. 1.83; melts at 111°; boils at 550°; easily ignited; very poisonous; its vapors produce necrosis of the jaw-bone, and horrible suffering to workmen engaged in its manufacture; exists in five forms. 1st. The Transparent, just described. 2d. White; formed by exposing the first to light under water, which renders it opaque, and less fusible. 3d. Black, by suddenly cooling melted phosphorus. 4th. Viscous; suddenly cooling phosphorus, heated to near its boiling-point. 5th. Red, by keeping phosphorus for 48 hours, at a temperature of about 480°. This variety does not fume, is hard to ignite, not poisonous; melts at 482°, and may be restored to the transparent condition by heating to 500° out of contact with air. Phosphorus cannot be crystallized by fusion, but from its solution in essential oils, sulphide of phosphorus, and sulphide of carbon, it deposits rhomboidal dodecahedrons, and burns under hot water in a jet of Oxygen.

Test. — Gives green color to hydrogen flame.

Use. — For friction matches.

Compounds with Oxygen.

1st. **Oxide of Phosphorus**—P_2O. Formed in small quantity, when oxygen is burned under water; a yellow powder

2d. **Hypophosphorous Acid**—PO.   Syrupy liquid.

3d. **Phosphorous Acid** — PO_3.   A white deliquescent, inflammable powder.

4th. **Phosphoric Acid.** — PO_5.   This is formed as a snowy powder, when phosphorus burns in oxygen.

Use.—Its intense avidity for water makes it one of the best *desiccating*, or drying agents, known to chemists.

Hydrates of Phosphoric Acid.—Besides this anhydride of phosphoric acid, three different hydrates of phosphoric acid are known:

1st. Protohydrate, or Metaphosphoric acid, HO,PO_5.

2d. Deutohydrate, or Pyrophosphoric acid, $2 HO,PO_5$

3d. Tritohydrate, or Tribasic Phosphoric acid, $3HO,PO_5$.

They are remarkable for forming with bases, three entirely different classes of salts, containing, respectively, one, two, and three, equivalents of water, or a base.

Compounds with Hydrogen.

They are three in number; viz. P_2H, PH_2, and PH_3. The first is solid; the second liquid; and the third is a gas, at ordinary temperatures; the last is the most important, and is known as

Phosphuretted Hydrogen Gas. — It is prepared by heating Phosphorus with concentrated solution of caustic potassa, in a flask, carefully filled with these materials; Hypophosphite of Potassa is formed at the same time; $4 P + 6 HO + 3 (KO,HO) = 3 (KO,PH_2O_2) + PH_3$.

Fig. 144.

Properties. —When the gas so obtained is allowed to escape into the air through the waters of the pneumatic trough, each bubble, as it breaks, takes fire spontaneously, and produces a snowy white wreath of phosphoric acid, which curls inward as it ascends.

Or, if fragments of Phosphide of Calcium

are thrown into a glass of water, mutual decomposition will ensue, the oxygen of the water going to the calcium, and the phosphorus and hydrogen uniting, and escaping in bubbles, which ignite as they reach the air. (See Fig. 144.)

Combination with Iodine. — Phosphorus combines with Iodine so readily that these two bodies will unite in the solid form, at ordinary temperatures, with great vigor. Thus, if we throw a few flakes of Iodine upon a bit of Phosphorus, they will, at once, combine igniting the latter.

METALS.

Properties of the Metals.

The metals are mostly characterized by a peculiar brilliancy, termed the *metallic lustre*. This is lost, however, when they are finely powdered, but may be restored by friction with a hard body.

When in the massive state, they are *opaque*, but if reduced to leaves of excessive thinness, they transmit light; gold foil, for example, if not more than $\frac{1}{300000}$ inch thick, appears green when held between a bright light and the eye.

Color. — Silver, platinum, tin, cadmium, and palladium, are almost white; lead and zinc are blue; iron and arsenic, grey; calcium and barium, pale yellow; gold, bright yellow; and copper, red.

Smell and Taste. — Iron, tin, copper, and lead, when rubbed by the hand, emit a disagreeable smell, peculiar to themselves; when arsenic is volatilized, it evolves a powerful odor of garlic. Some metals, as iron, and tin, have a nauseating *metallic* taste.

Hardness, Brittleness, and Tenacity. — The *hardness* of

the metals is very variable: while potassium may be moulded like wax, and lead may be dented by the finger-nail, steel may be rendered hard enough to scratch steel like the diamond.

So with regard to their *brittleness* and *tenacity.* Some, like antimony, arsenic, and bismuth, may easily be crushed to powder; while others, as gold and silver, resist very great pressure. An iron wire, an inch thick, will support, without breaking, twice as much as one of platinum having the same diameter, three times that of silver, ten times more than tin, and twenty times as much as zinc.

Malleability and Ductility. — The order of *malleability,* by which is meant the property possessed by metals of being rolled or hammered into leaves, is as follows : —

1. Gold; 2. Silver; 3. Copper; 4. Tin; 5. Platinum; 6. Lead; 7. Zinc; 8. Iron.

If the metals were arranged according to their *ductility,* or the ease with which they are drawn into wire, the order would be :—

1. Gold; 2. Silver; 3. Platinum; 4. Iron; 5. Copper; 6. Zinc; 7. Tin; 8. Lead.

Their SPECIFIC GRAVITY varies from that of Lithium, 0.593, to that of Platinum, 21.5; their FUSIBILITY, from —39°, the freezing-point of mercury, to 3844°, the fusing-point of forged iron, and even far beyond this, to where platinum melts in the oxyhydrogen flame.

Chemical Properties of the Metals.

Action of Oxygen and of Water on the Metals. — Potassium and Sodium combine with Oxygen, and decompose water at the ordinary temperature; Iron, Lead, etc., only when highly heated; and Gold, Platinum, Iridium, etc., cannot be directly combined with Oxygen, or be made to decompose water at any temperature.

Classification of the Metals. — The metals are therefore arranged in six groups: —

1. *Metals of the* ALKALIES: *Potassium, Sodium, Lithium,* and *Ammonium.*

2. *Metals of the* ALKALINE EARTHS: *Barium, Strontium, Calcium,* and *Magnesium.*

Termed alkaline because they have a caustic action upon animal matters, and earths because their oxides are insoluble in water.

3. *Metals of the* EARTHS: *Aluminum, Glucinum, Zirconium, Thorinum, Yttrium, Erbium, Terbium, Cerium, Lanthanum, Didymium.*

4. *Metals, whose Oxides form powerful* BASES: *Manganese, Iron, Chromium, Nickel, Cobalt, Copper, Zinc, Cadmium, Bismuth, Lead, Uranium.*

5. *Metals, whose Oxides form weak Bases, or* ACIDS: *Vanadium, Tungsten, Molybdenum, Tantalum, Niobium, Titanium, Tin, Antimony, Arsenic, Tellurium.*

6. **Noble Metals.** — *Gold, Mercury, Silver, Platinum, Palladium, Iridium, Osmium, Ruthenium, Rhodium.*

Salts.

Definitions. — A salt is a body formed by the combination of an acid with a base.

When an oxacid is united with an oxygen base it is termed an *oxysalt:* $KO + CO_2 = KO,CO_2$, Carbonate of Potash.

The union of a Sulphur acid with a Sulphur base gives rise to a *sulphosalt:* $KS + CS_2 = KS,CS_2$, Sulphocarbonate of Potash.

When a hydracid unites with a base it forms water and a binary compound, termed a haloid salt: $KO + HCl = KCl + HO$; $NaO + HI = HO + NaI$; $CaO + HF = CaF + HO$; $H_2O + HCy = HO + H_2Cy$.

A Neutral Salt is one which contains as many equiva-

lents of acid as there are equivalents of Oxygen in the base, as CaO,CO_2, Carbonate of Lime; $PdO_2,2SO_3$, Sulphate of Binoxide of Palladium; $Al_2O_3,3SO_3$, Sulphate of Alumina.

When a neutral salt reddens blue litmus paper it is termed a *neutral salt with an acid reaction*, as Nitrate of Copper, CuO,NO_5.

If it turns red litmus-paper blue it is known as a *neutral* salt with a basic reaction, as Carbonate of Potash, KO,CO_2.

An **Acid Salt** is one which contains more equivalents of acid than there are equivalents of Oxygen in the base, as Bichromate of Potash, $KO,2CrO_3$.

Note. — Salts are also termed *monobasic, bibasic,* and *tribasic,* according as they are formed by the union of a base with a monobasic, bibasic, or tribasic acid.

A **Monobasic Acid** is one which combines with but one equivalent of a base, as *Sulphuric, Nitric,* etc.

A **Bibasic Acid** neutralizes two equivalents of the base, as the *Pyrophosphoric, Tartaric, Racemic,* and *Gallic* acids.

A **Tribasic Acid** combines with three equivalents of the base, as the *Tannic, Phosphorous, Citric* acids, etc.

A **Basic or Sub-salt** is one which contains fewer equivalents of acid than there are equivalents of Oxygen in the base, as Sub-Sulphate of the Sesquioxide of iron (Fe_2O_3,SO_3).

A **Double Salt** is one formed by the combination of two salts. The electro-negative body is usually the same in both salts, as $KO,SO_3+Al_2O_3,3SO_3+24HO$, Alum, or the double Sulphate of Potash and Alumina; $KCl+PtCl_2$, double Chloride of Potassium and Platinum.

GROUP I.

Sym. K. **POTASSIUM.** Eq. 39.

Isolated by Davy, in 1807, from moistened Hydrate of potassa placed in contact with the poles of a very powerful galvanic battery.

Preparation.—When Carbonate of Potassa and charcoal are intimately mixed together and subjected to intense heat, carbonic oxide and potassium vapor are set free. The latter is solidified by cold, and collected in a proper receiver, $KO,CO_2 + 2C = K + 3CO$.

Properties.—A bluish-white metal, which is brittle and crystalline at 32°, soft at 60°, liquid at 130°. Its specific gravity being only 0.865, Potassium will float upon water. Enters directly into combination with the halogens, and with Sulphur, Selenium and Tellurium, burning vividly when heated with them. So strong is its affinity for oxygen that it cannot be preserved in the open air, but only in a vacuum, or under the surface of some liquid, like Naphtha, which does not contain oxygen. When a lump of Potassium is thrown upon water, it unites with the Oxygen of that compound, forming potash, and setting free the Hydrogen. The heat developed in this action is so great as to render the Potassium red hot, and to ignite the liberated Hydrogen, which burns with a flame tinged purple by the vapor of the Potassium, which also burns.

Compounds with Oxygen.

Teroxide of Potassium — KO_3. Formed when potassium is heated in an excess of dry oxygen gas.

Potassa—KO. Generated by the oxidation of potassium in dry air. Known in chemistry as a reagent only in the form of HYDRATE OF POTASSA, KO,HO.

Sources.—Found combined with Silica in Mica and Fel-

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spar.   By decomposition of these two minerals, it passes into the soil.   The fertility of land depends in great measure upon the quantity of Potassa which it contains. From the earth it is taken up by plants, and it is from the ashes of burnt trees that the carbonate of potash, or *pearlash* of commerce, is obtained.

Preparation.—This hydrate is manufactured by dissolving Carbonate of Potassa in 10 or 12 times its weight of water, and adding to the boiling solution a quantity of caustic lime, equal in weight to half the Carbonate of Potassa used, $KO,CO_2 + CaO,HO = KO,HO + CaO,CO_2$.

Uses.—The glass maker unites it with sand to make Silicate of Potassa, one of the components of glass; the soap-maker unites it with a fatty acid to form soft soap; the chemist absorbs carbonic acid with it, and decomposes by it all those metallic salts, the bases of which are insoluble in water.   It is very alkaline, and unctuous to the touch; it instantly alters, and finally destroys the skin, for which reason it is employed as an escharotic, under the name of *caustic* potash.   Ignited with the insoluble silicates, it renders them soluble in acids: this operation must be performed in silver capsules.

Compounds with the Halogens.

Chloride of Potassium, KCl, is extracted from *kelp*, the ashes of burnt sea-weeds.   It is used in large quantities, as a source of potassa in alum manufacture.   The slaty clay which is used for making alum is filled with bisulphide of iron, FeS_2; hence, on roasting and exposing to air and moisture, sulphate of the protoxide of iron and sulphate of alumina are formed.   But alum is a double sulphate of *potassa* and alumina.   Chloride of potassium is therefore employed to decompose the sulphate of iron: $FeO,SO_3 + Al_2O_3, 3SO_3 + KCl + Aq = (KO,SO_3 + Al_2O_3, 3SO_3 + 24HO) + FeCl$.

Also, to effect the decomposition of nitrate of lime in

one mode of manufacturing saltpetre: $CaO,NO_5 + KCl = KO,NO_5 + CaCl$.

Iodide of Potassium, KI, is procured by digesting 2 parts of iodine and 1 of iron in 10 parts of water; the protiodide of iron so formed is afterwards converted into iodide of potassium by carbonate of potassa: $Fe + I = FeI$ and $FeI + KO,CO_2 = KI + FeO,CO_2$.

Uses.—In the manufacture of the metallic iodides; to dissolve the Iodide of Silver employed in iodizing photographic paper, and as a remedy for glandular swellings.

Compounds with Acids. Potassa Salts.

Carbonate of Potassa—KO,CO_2. In commerce called *Vegetable Alkali, Salt of Tartar, Dulcified Alkali, Pearlash,* or simply *Potash.*

Preparation.—Potassa, KO, exists in large quantities in plants, combined with various organic acids, such as *Malic, Acetic, Oxalic, Tartaric,* etc. These salts are all converted, by burning, into Carbonate of Potassa, and the latter may therefore be obtained by making a *lye* of wood-ashes, and evaporating until the carbonate of potassa crystallizes out. Birch-ash yields the purest potash, pine ashes the least; herbaceous plants furnish more than shrubs, and shrubs more than timber; the quantity afforded by the leaves is to that procured from heartwood as 25 to 1.

Uses.—In the manufacture of *soft* soaps, crystal glass, Prussian blue, and sometimes to decompose the nitrates of lime and magnesia, employed in making saltpetre. When changed to the bicarbonate or *sal aëratus* ($KO,CO_2 + HO,CO_2$), by passing a current of Carbonic acid through a solution of the carbonate, it is used in the treatment of gout and the like, and mixed with citric or tartaric acid, to make *effervescing draughts.*

Sulphate of Potassa, KO,SO_3, obtained by neutralizing

the *Bisulphate of Potassa* ($KO,SO_3 + HO,SO_3$), which is left as a residue in the manufacture of Nitric acid with KO,CO_2, is used as a gentle laxative. In analysis, the former salt serves to detect and separate baryta and strontia; the latter as a flux for salts, or metallic oxides, which are required to be acted upon by an acid at a high temperature.

Nitrate of Potassa — KO,NO_5.   Salt of Nitre, Nitre, Saltpetre.

Source. — Formed abundantly in the hot weather succeeding rain-storms, in certain soils of Spain, Egypt, Persia, and the East Indies, which are rich in potash. (See Ammonia.) Incrusts the interiors of many caverns in the West, and in Ceylon. Artificially prepared by the oxidation of ammonia in the presence of a powerful base in *nitre* plantations; animal refuse of all kinds, the cleaning of sinks, stables, etc., are thrown together with old mortar, plaster from ceilings, etc., into great heaps. After three years these nitre beds are washed, and yield to every cubic foot 4 or 5 ounces of nitre.

Fig. 145.

This salt crystallizes in the form of an hexagonal prism. A slice of this, cut perpendicular to its axis, viewed between two polarizing bodies, as in Fig. 54, or 55, shows the system of colored rings and dark brushes, indicated in Fig. 60, when the plane of its two optical axes coincides with the plane of the polarizer, and the system represented in Fig. 145, when these planes are slightly inclined.

Uses.—Nitre is extremely valuable on account of the facility with which it yields up its oxygen. It is constantly employed to oxidize the metallic sulphides into

sulphates, carbon into carbonic acid, etc. Ex. Rapid combustion (*deflagration*) of a mixture of carbon and nitre, or of sulphide of antimony (SbS_3), or sulphur with nitre, when touched by an incandescent body. This property of nitre gives it wonderful adaptation for its use in

Gunpowder.—Gunpowder, used in France, Prussia, and the United States in war, consists of 75 parts of saltpetre, $12\frac{1}{2}$ parts of charcoal, and $12\frac{1}{2}$ parts of sulphur. The saltpetre starts the detonation by giving up all its Oxygen to the Carbon to form Carbonic oxide and Carbonic acid gases, the Potassium and Nitrogen being thus set free. The former straightway seizes upon the Sulphur to form vaporous Bisulphide of Potassium, the latter flies off as gas: $KO,NO_5 + S_2 + 4C = KS_2 + 2CO + 2CO_2 + N$. The temperature at the moment of explosion rises to $2200°$, high enough to melt gold and copper coin; and dilates the liberated gases, already occupying an enormous volume, until an amount of powder which filled 1 cubic foot of the gun, after firing, expands to 2000 cubic feet.

Besides this important use of nitre in gun powder, butchers employ it to preserve meats; physicians as a medicine. Lucifer matches are made with it.

Chlorate of Potash — KO,ClO_5. Largely manufactured by passing Chlorine through a thin cream of 1 part of Chloride of Potassium and 2 parts of Hydrate of Lime dissolved in water: $KCl + CaO + 6Cl = KO,ClO_5 + 6CaCl$. Ex. Rubbed with charcoal, sulphur, and phosphorus the mixture explodes, in consequence of the rapid oxidation of these bodies by the Chlorate.

Uses.—By the chemist and calico-printer as an oxidizing agent; in lucifer matches; and in percussion powder for gun-caps. The friction tubes for cannon-firing are charged with a mixture of 2 parts of Chlorate of Potash, 2 of Sul-

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phide of Antimony, and 1 of powdered glass. A mixture of Chlorate of Potash, dried Ferrocyanide of Potassium and Sugar has been used for blasting, under the name of *white gunpowder;* but the ease with which it explodes by friction has rendered its manufacture dangerous.

Test.—When a strong solution of *Bichloride of Platinum* is poured into a concentrated solution of a potash salt, a yellow double Chloride of Potassium and Platinum ($KCl + PtCl_2$) precipitates.

Sym. Na.　　　　　　**SODIUM.**　　　　　　Eq. 23.

Discovered by Davy in 1807, and obtained by him in the same manner as Potassium. Prepared like Potassium for commercial uses.

Properties.—A bluish-white metal; soft at common temperatures, melts at 194°. Decomposes cold water with the evolution of heat but not of light. The Oxide, Sulphides, and Haloids of Sodium correspond in properties and mode of formation with those of Potassium. Sp. Gr. 0.972.

Chloride of Sodium—NaCl. Sea Mineral, or Rock Salt.

Sources.— Found in Poland, England, Spain, and other places as a rocky deposit, often of great thickness and extent. Obtained likewise by evaporating in salt-pans the waters of the ocean, and those pumped from the salt-wells of Western Virginia and Pennsylvania.

Uses.—To season food; in the manufacture of Sulphate and Carbonate of Soda, of Hydrochloric acid, the bleaching Chlorides, and Chlorine; in forming salt-glaze upon pottery; in manufacturing soap; in preserving meat.

Sulphate of Soda, NaO,SO_3, is manufactured on a vast scale in Leblanc's process for making Carbonate of Soda, by causing Sulphuric acid to react upon common salt; thus, $NaCl + HO,SO_3 = NaO,SO_3 + HCl$. It was formerly also in favorite use as a saline cathartic. under the

name of *Glauber's salt*, but it has gradually been replaced by Sulphate and Citrate of Magnesia.

Carbonate of Soda, NaO,CO_2, is prepared by throwing into an elliptical reverberatory furnace 1000 lbs. of *salt cake*, or Anhydrous Sulphate of Soda, obtained by the above reaction, intimately mixed with 1000 lbs. of dry chalk, and 350 lbs. of crushed coal. The Sulphate of Soda is reduced by the coal to Sulphide of Sodium, $NaO,SO + 4C = NaS + 4CO$; and this Sulphide effects a double decomposition of the Carbonate of Lime, to form Carbonate of Soda and Sulphide of Calcium, $NaS + CaO,CO_2 = NaO,CO_2 + CaS$. Fifteen hundred pounds of this *crude artificial soda* or *black ash* may be obtained from the preceding charge. Crystallized from its solution, it is known in commerce as *sal soda*.

Uses. — The soap-makers use vast quantities of black ash to make from it, by treatment with milk of lime, their caustic Soda, or *Soda lye*, employed in the manufacture of hard soap: $NaO,CO_2 + CaO,HO = NaO,HO + CaO, CO_2$. Used as a detergent by the calico-printer, and, under the name of *washing soda*, in the kitchen. It unites with the grease in the dirty linen, and forms with it a kind of soap. In the laundry for softening hard waters, by forming with the soluble salts of Lime and Magnesia insoluble Carbonates. In the manufacture of glass. Treated with excess of Carbonic acid it is converted into Bicarbonate or *Supercarbonate* of Soda ($NaO, CO_2 + HO,CO_2$). It is mixed with Rochelle salt in the blue paper which is sold, along with a white envelope enclosing Tartaric acid, by druggists, as *Seidlitz powders*.

Phosphates of Soda.

Phosphoric Acid forms with Soda several crystallizable salts, which differ from each other in the number of equivalents of Soda united with one equivalent of the acid. viz :
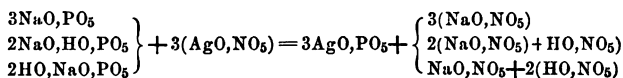
(*a*) **The Tribasic Phosphates of Soda,** which are three in number : —

1st. *Neutral Tribasic Phosphate,* or *Subphosphate of Soda* ($3NaO,PO_5+24Aq$).

2nd. *Rhombic Phosphate of Soda,* ($2NaO,HO,PO_5 + 24Aq$). From this salt all the other Phosphates of Soda are formed. It has been longest known, and is familiar under the name of Commercial Phosphate of Soda.

3rd. *Biphosphate of Soda,* ($2HO,NaO,PO_5+24Aq$).

Test. — These three tribasic phosphates give with Nitrate of Silver a yellow precipitate. They always require three equivalents of the salt, with which they react: thus,

$$\left. \begin{array}{l} 3NaO,PO_5 \\ 2NaO,HO,PO_5 \\ 2HO,NaO,PO_5 \end{array} \right\} +3(AgO,NO_5)=3AgO,PO_5+ \left\{ \begin{array}{l} 3(NaO,NO_5) \\ 2(NaO,NO_5)+HO,NO_5 \\ NaO,NO_5+2(HO,NO_5) \end{array} \right.$$

(*b*) **Pyrophosphate of Soda** ($2NaO,PO_5+10Aq$).

Test.—Gives a dense white precipitate with Nitrate of Silver. Reacts with two equivalents of another salt: thus,

$$2NaO,PO_5+2(AgO,NO_5)=2AgO,PO_5+2(NaO,NO_5).$$
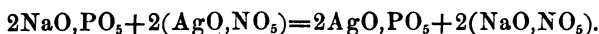
(*c*) **Metaphosphate of Soda** (NaO,PO_5).

Test. — Gives a gelatinous white precipitate with Ni trate of Silver. Reacts with one equivalent of another salt : $NaO,PO_5+AgO,NO_5=AgO,PO_5+NaO,NO_5$.

Uses.—Phosphate of Soda ($2NaO,HO,PO_5$) precipitates all the alkaline earths and metallic oxides. After the oxides of the heavy metals have been separated, it serves in analysis as a test for the alkaline earths in general; and after the separation of Baryta, Strontia, and Lime it is used, in conjunction with Ammonia, to precipitate Magnesia, as the basic Phosphate of Magnesia and Ammonia (NH_4O,MgO,HO,PO_5). Combined with Ammonia as *microcosmic salt* (NaO,NH_4O,HO,PO_5), it is frequently preferred to Borax as a flux before the blowpipe, because with many substances it gives a more brilliantly colored bead.

Biborate of Soda—$NaO,2BO_3+10Aq.$ Borax.

Sources. — For many years the crude Borax, or *Tincal* of commerce, was obtained by evaporation of the waters of certain lakes in Thibet.   Now manufactured from the Boracic acid present in the lagunes of Tuscany, by neutralizing it with Carbonate of Soda, and allowing the saturated solution to crystallize.

Uses.—When two oxidizable metals, such as Copper and Iron, are to be soldered together, the brazier sprinkles their surfaces with Borax.   This dissolves off the oxide, which would otherwise prevent their union, as fast as it is formed.   The goldsmith also employs it, in both refining and soldering the precious metals.   It enters into enamels to render them more fusible, and into the composition of easily melted glasses ; it is employed in fixing colors upon porcelain, and for the glazing of some potteries.   The free Boracic acid, which is present in Borax, along with the Borate of Soda (commonly called Biborate of soda), has a strong affinity for metallic oxides at high temperatures. It consequently forms with them and the Borate of Soda before the blowpipe double borates, which have different colors, and which serve to detect the different metals ; with Oxide of Chromium, *emerald* green; with Oxide of Cobalt, a deep *blue ;* with Oxide of Copper, a pale *green :* with Oxide of Tin, an *opal;* with Oxide of Manganese, a *violet,* etc.

Sym. L.   **LITHIUM.**   **Eq. 7.**

Isolated by Davy by means of the galvanic battery, and named from λίθος, *a stone,* because it is found only in the minerals, *lepidolite, spodumene,* and *petalite.*

Properties. —A white metal, fusible at 356°, and burning with a brilliant white light.   It is the *lightest of metals.* Sp. Gr. 0.5936.

Tests.—A purplish red color in the blowpipe flame, and one intensely bright red band in the spectroscope.

Sym. NH₄, or Am. AMMONIUM (hypothetical).   Eq. 18.

Ammoniacal Amalgam. — Ammonium has never been isolated, but is thought to exist in combination with Mercury in the compound which is formed when a concentrated solution of Sal Ammoniac is poured upon Sodium Amalgam. The latter increases in bulk to 10 times its original volume, and acquires a pasty consistence, but nevertheless *preserves its metallic lustre.* On applying heat, Hydrogen and Ammonia are rapidly given off, and pure Mercury left behind. From the character of its salts, Ammonium is placed among the alkaline metals.

Oxide of Ammonium—$NH_4O.$ Ammonia. When Ammonia, NH_3, enters into combination with anhydrous Sulphuric acid, SO_3, it forms, not the ordinary salt, Sulphate of Ammonia, but a sulphate of very different properties. It is only when the *hydrated* acid, HO,SO_3, is combined with Ammonia that the regular Sulphate of Ammonia is formed. Therefore the basic water of the acid must have united with the gaseous Ammonia to form a new base, and this new base is what we shall henceforth regard as Ammonia, NH_4O: thus, $NH_3 + HO,SO_3 = NH_4O,SO_3$.

Chloride of Ammonium, *Muriate of Ammonia, Sal ammoniac* — $NH_4,Cl.$ The foregoing theory is strengthened by the fact, that when dry Hydrochloric acid is mixed with dry Ammoniacal gas, a white solid is formed which is ordinary Sal Ammoniac, and that this Sal Ammoniac, if dissolved in water, gives with Nitrate of Silver the same curdy precipitate as is formed when any other chloride reacts with Nitrate of Silver: that is to say, Sal Ammo-

niac is not Hydrochlorate of Ammonia, NH_3HCl, but Chloride of Ammonium, NH_4Cl.

Sources.—It derives its name from *Ammon,* the ancient appellation of Egypt, where it was originally manufactured by the dry distillation of camel's dung. It was also termed *Spirit of Hartshorn,* because obtained from horn-shavings by heat. Now manufactured by neutralizing, with hydrochloric acid, *ammoniacal liquor,* or water laden with ammoniacal salts, tar, and other impurities taken up in washing coal-gas.

Uses. — Owing to its great solubility and the resulting depression of temperature, it is used in freezing mixtures; in the preparation of the sesquicarbonate of ammonia $(2NH_4O,3CO_2)$, or *smelling-salts* of the shops. To remove rust from metals, particularly copper; in dyeing; in preference to chloride of sodium and chloride of barium for *salting* photographic paper; it is sprinkled over iron-filings previously mixed with one hundredth part of sulphur, to form a lute for cementing iron into stone. A mixture of the chlorides of silver and ammonium is sometimes employed for *silvering* copper and brass without heat.

Uses of other Ammoniacal Salts.

Carbonate of Ammonia, NH_4O,CO_2, is preferred, in consequence of its volatility on heating, to the carbonate of soda for precipitating the metallic oxides and earths. It is principally employed to separate the alkaline earths from magnesia, and to separate also sulphide of arsenic, which is soluble in it, from sulphide of antimony which is insoluble. *Molybdate of Ammonia,* NH_4O,MoO_3, when added in great excess to their acid salts, serves to detect the faintest trace of phosphoric and arsenic acids. *Oxalate of Ammonia,* NH_4O,C_2O_3, is a most delicate test of lime, precipitating it as an oxalate, $CaO,SO_3 + NH_4O,C_2O_3$ $= CaO,C_2O_3 + NH_4O,SO_3$. *Hydrosulphate of Ammonia,*

NH_4S,HS, is employed to detect many of the metals by precipitating them as differently colored sulphides, and is used like sulphide of potassium for bronzing electro-plated medals.

GROUP II.

Metals of the Alkaline Earths.

Sym. Ba.   **BARIUM.**   Eq. 68.5.

History. — Obtained by Davy, in 1808, from moistened carbonate of baryta in contact with mercury, when the latter was made the positive pole of a powerful galvanic battery. It may also be procured by passing potassium vapor over baryta heated to redness in an iron tube. Derives its name from βαρύς, heavy, owing to the great weight of its compounds.

Properties. — A white metal, fusible under a red heat. Decomposes water with rapid evolution of hydrogen.

Baryta, BaO, exists as a sulphate, *heavy spar*, which often constitute the *vein-stone* or *gangue* in mines, and as a carbonate, *witherite.* Obtained by calcination of nitrate of baryta. When heated to redness in an atmosphere of oxygen, it is converted into the binoxide which is interesting as the source of binoxide of hydrogen.

Uses. — Hydrated baryta, BaO,HO, and also the *Chloride of barium*, $BaCl$, and *Nitrate of baryta*, BaO,NO_5, are employed to precipitate Sulphuric acid by forming with it, even in very dilute solutions, an insoluble *Sulphate of baryta*, BaO,SO_3. Fifty grains of nitrate of baryta mixed with 150 of sulphur, 100 of chlorate of potassa, and 25 of lampblack, constitute the "*green-fire*," of the pyrotechnist.

As a carbonate, BaO,CO_2, it is employed in the analysis of siliceous minerals, which are insoluble in acids, forming when fused with them a silicate of baryta, and a soluble carbonate of the mineral oxide to be determined.

The sulphate (BaO,SO_3) is the *permanent white* of water-color artists; it is also employed to adulterate white lead. When mingled in excess with this latter pigment it forms *Dutch white;* in equal amount, *Hamburg,* and in lesser quantity, *Venice white.* But it becomes, when ground with oil, translucent, and impairs the opacity of the lead paint.

Character of the Salts.—Colorless and poisonous, the best antidote being Epsom salts. Give a white precipitate with sulphuric acid, which is insoluble in acids.

Sym. Sr.   **STRONTIUM.**   **Eq. 43.84.**

Discovered by Davy, at the same time and in the same way as Barium, which it closely resembles in properties. It is found native as a carbonate, *strontianite,* and as a sulphate, *celestine;* from the former, which was first found at the mining village of Strontian, in Scotland, it derives its name. All the salts of strontia are distinguished by the crimson tinge which they impart to the blowpipe flame; and "red-fire" is made by mixing 40 drachms of *dry* Nitrate of Strontia (SrO,NO_5), with 10 of Chlorate of Potassa, 13 of Sulphur, and 4 of Sulphide of Antimony.

Sym. Ca.   **CALCIUM.**   **Eq. 20.**

Isolated by Davy, in 1808, with the galvanic battery, from moist lime.

Properties.—As obtained by the fusion of sodium with iodide of calcium ($CaI + Na = Ca + NaI$), it is a light yellow metal, which is very malleable, and which slowly decomposes water at ordinary temperatures. It enters into combination with oxygen, chlorine, bromine, iodine, and sulphur, when heated with them; the union being accompanied by vivid light. Sp. Gr. 1.578.

Lime— CaO. Caustic, or Quicklime, is obtained by burning lime in kilns having the form of a cone, inverted

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and truncated. Four parts of coal and one of lime having been thrown in from above, the fire is lighted by means of fagots and gradually spreads throughout the kiln. As fast as the carbonic acid has been driven off, the lime is removed by openings at the base of the kiln, while fresh layers of carbonate of lime and coal are added at the top.

Uses.—When the oxyhydrogen flame is turned upon cylinders of quicklime, it causes them to glow with the intense brilliancy known as the Drummond Light. Mixed with water, a hydrate of lime, which is commonly known as *slaked lime* (CaO,HO), is formed. The latter has the power of uniting with the carbonic acid which is present in the atmosphere, and forming with it a solid carbonate of lime. Hence its utility, when stiffened with sand, in *mortars* and *cements*.

Lime is also employed to loosen hair from hides in tanning; to purify coal-gas, by absorbing from it sulphuretted hydrogen and carbonic acid; to set free the stearic acid used for candles, from the fatty base; to *defecate* sugars, or to remove the acetic and lactic acids present in the raw syrup, by forming with them insoluble acetates and lactates. It acts as a manure, by decomposing the organic matter which is present in the soil, and making it soluble in water. One ounce of lime is soluble in about 700 ounces of water; and its solution, which is known as *lime-water*, is valuable as a test for carbonic acid, in consequence of the turbidity arising from the faintest trace of the latter.

When a stream of chlorine is passed over masses of slaked lime, a mixture of Chloride of calcium and Hypochlorite of lime is formed, which is familiarly known as *Chloride of lime* or *Bleaching-powder:* $2CaO,HO + 2Cl = CaCl + CaO,ClO$.

The Chloride of Calcium, CaCl, alluded to above, has an intense avidity for moisture; and it is therefore used in the drying or desiccation of gases.

Carbonate of Lime, CaO,CO_2, in the amorphous condition, constitutes the different varieties of *limestone, oolite, chalk, alabaster,* and *lithographic stone.* Crystallized in rhombohedra, it is distinguished as *calcite* and *Iceland spar.*

Sections of this, as described on page 67, show, with polarizing instruments, colored rings and crosses, as represented in Fig. 57, and Fig. 146; the first with the polarizer and analizer " crossed," the last with these parallel. In six-sided prisms, CaO,CO_2 occurs as *aragonite ;* in minute granular crystals, as *marble* in its endless

Fig. 146.

forms. It enters largely into the bony structure of men and animals, and is the chief component of corals and of shells. It is soluble in water containing carbonic acid; and when the latter is driven off by heat or in any other way, it is again deposited. In this manner are formed the incrustations on the sides of steam boilers, which so frequently lead to explosions; and the *stalactites,* which depend from the ceiling, and the *stalagmites,* that rise from the floor, of caverns in limestone districts.

Sulphate of Lime — $CaO,SO_3 + 2HO$. Gypsum is especially valuable as affording a powder known as *Plaster of Paris,* when its water of cystallization has been driven off by a heat not exceeding 500°. This plaster has the singular property of expanding, when made into a paste with water, and then, in the course of a few minutes, of *setting,* or changing to a solid mass. It is therefore largely employed for copying medals, busts, statues, for moulds in stereotyping, etc., and as cement, stucco, etc.

Tribasic Phosphate of Lime, $3CaO,PO_5$, forms more than half of the bones of men and other animals. When converted to the acid, or *superphosphate of lime* ($CaO, 2HO,PO_5$), by heating with two-thirds its weight of sulphuric acid, it is largely employed in the manufacture of phosphorus, and as a manure.

Character of Lime Salts.—They are all colorless, and afford, with oxalate of ammonia, a copious precipitate of oxalate of lime, $CaO,C_2O_3 + 2HO$.

Sym. Mg.   **MAGNESIUM.**   Eq. 12.

Discovered by Bussy, in 1828.

It is prepared by heating the anhydrous double Chloride of Magnesium and Sodium with metallic Sodium. The process for manufacturing on the large scale was patented and is carried on in England by Sonstadt; in this country it is made under the same patent by the American Magnesium Company, Boston, Massachusetts. (See Journal of Franklin Institute, Vol. 51, p. 69.

Sources. — Combined with carbonic acid, as a double carbonate of lime and magnesia, forming magnesian limestone, or dolomite. Exists in the waters of the ocean, as a chloride, and of many mineral springs, as a sulphate. Enters into the composition of many rocks and minerals.

Properties. — Resembles silver in color and lustre, zinc in fusibility and volatility. Very ductile, and malleable; crystallizes in octahedrons. Not acted upon by cold, oxidized by hot water. Burns in air producing a brilliant white light, capable of employment for illuminating and photographic purposes. Sp. Gr. 1.7.

Fig. 147.

In order to make its combustion regular in these cases, the magnesium, in the form of a narrow ribbon, is fed by clockwork, from
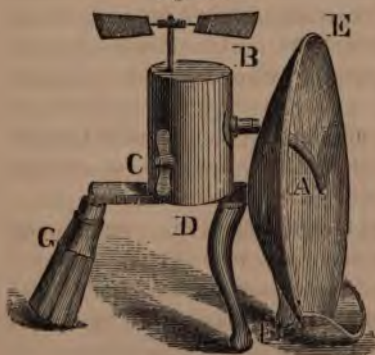
a brass nozzle, A, beyond which it burns. This apparatus, known as a Magnesium Lamp, is shown in Fig. 147. The clock-work is contained in B C, its motion is controlled by the fly-wheel, B, and it is wound up by the key, D. The mirror, E F, reflects, and concentrates the light, and the whole apparatus may rest on a table, or be held by the handle, G. This light has been used to photograph dark interiors, coal-mines, the Pyramids, etc., and to take photographic portraits, at night. This light is superior in amount to a good lime light, and approaches even the electric light obtained from 50 Bunsen 7 inch cells. In actinic force it surpasses all other artificial lights.

Oxide of Magnesium—MgO. Magnesia; Calcined Magnesia. Prepared by driving off the carbonic acid and water contained in *magnesia alba* by long continued heat; a soft, bulky, white, tasteless, and nearly insoluble powder.

Carbonate of Magnesia—MgO,CO_2. Occurs in nature, in rhombohedral crystals—*magnesite*. Mixed with hydrate of magnesia, it forms the subcarbonate of magnesia, or *magnesia alba* of pharmacy, $4(MgO,CO_2 + MgO,HO + 6HO.)$

Sulphate of Magnesia—$MgO,SO_3 + 6HO$. Epsom Salts. Formed by dissolving Magnesite in Sulphuric acid, and separating the sparingly soluble sulphate of lime by filtration; thus, $MgO,CO_2 + HO,SO_3 = MgO,SO_3 + HO + CO_2$.

Phosphate of Magnesia and Ammonia—$2MgO,NH_4O,PO_5 + 12HO$. When it is desired to remove magnesia from solution, it may be done by adding some soluble phosphate, together with ammonia; when an insoluble phosphate of magnesia and ammonia is formed.

Silicates of Magnesia.—*Occur native* as Talc, $2(MgO, SiO_3) + 2MgO,3SiO_3$; Steatite or Soapstone, MgO,SiO_3

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$+ 2MgO,3SiO_2$; Meerschaum, $2MgO,3SiO_2 + 4Aq$; Serpentine, $2(MgO,SiO_2) + MgO + 2Aq$, and many others.

Character of the Magnesian Salts.—Bitter to the taste. Many magnesian minerals have a silky lustre, and feel unctuous to the touch.

Test.—A white precipitate, with Phosphate of ammonia.

GROUP III.

Metals of the Earths.

Sym. Al. **ALUMINUM.** Eq. 13.7.

First procured by Wohler, in 1827, by decomposing Chloride of Aluminum in a platinum tube, by means of Potassium, $Al_2Cl_3 + 3K = 3KCl + 2Al$.

Properties.—In color and hardness, aluminum closely resembles zinc. It may be rolled into very thin foil, and drawn out into fine wire. It conducts electricity almost with the rapidity of silver; struck with a hard body, it gives a clear and musical ring. On account of its lightness—being but $2\frac{1}{2}$ times heavier than water—and its inalterability in air, many attempts have been made to employ aluminum as a substitute for silver, in articles of jewelry, and table use. Sp. Gr. 2.5.

Sesquioxide of Aluminum, or Alumina—Al_2O_3. When this earth is found crystallized in nature, and of a dark red color, it is known as *oriental ruby;* when blue, as *sapphire;* green, *oriental emerald;* if it is yellow, it is called *oriental topaz;* and if violet, *oriental amethyst.* To the dark-colored and dingy crystals the name of *corundum* is given, and to the granular masses, so valuable for polishing, the term *emery* is applied.

It is obtained as a gelatinous hydrate, when carbonate of ammonia is added to the sulphate, or other salt of alumina: $Al_2O_3,3SO_3 + 3(NH_4O,CO_2) + Aq =$

$3HO,Al_2O_3 + 3(NH_4O,SO_3) + 3CO_2 + Aq.$ In this condition it dissolves readily in potash and acids, but if rendered anhydrous by ignition, it dissolves with difficulty.

Uses. — Alumina has a strong attraction for water, of which it retains no less than 15 per cent.; hence, the value of clay as an ingredient of the soil.

It forms with most coloring-matters, insoluble compounds, called *lakes*. If the dyer were to soak his calicoes in the dyestuff alone, the color would be removed from the cloth at the first washing. He first immerses them in a solution of some *mordant* like alumina, which has an attraction for both the cotton fibre and the coloring material, strong enough to resist the action of water. To obtain the alumina for this purpose, alum ($KO,SO_3 + Al_2O_3,3SO_3 + 24HO$), which has been manufactured by the process described under Chloride of Potassium, page 182, is decomposed by carbonate of soda; the cotton fibre forms a strong mechanical combination with the alumina thus set free, by which it is enabled to hold the coloring-matter fast.

Besides its above-mentioned use, alum is employed in the sizing of paper, the preparation of sheep-skins, and in clarifying sugars, etc.

Silicates of Alumina. — When silicate of alumina ($Al_2O_3,3SO_3$) is combined with silicate of lime (CaO, SiO_3), it produces a number of minerals, which have the remarkable property of boiling up, on being heated in the blowpipe flame, and are therefore called *zeolites*, from ζέω, *I boil*. Combined with the silicates of potassa, soda, lithia, or lime, silicate of alumina forms *feldspar*, and feldspar, when mingled with quartz and mica, produces the well-known *gneiss* and *granite* rocks. The beautiful *topaz* is a silicate of alumina combined with fluoride of aluminum, Al_2F_3; and the Bohemian *garnet*, so highly

prized for its intense blood-red color, is a silicate of alumina colored by the sesquioxides of iron and chromium.

Uses.—When the granite rocks crumble away beneath the slow but resistless action of storms and rain, they afford the different varieties of *clay*. The latter, when stained by sesquioxide of iron, is used as a pigment under the name of *yellow* and *red ochre;* if free from stains of iron it is called *pipe-clay*, and is largely manufactured into tobacco pipes. A peculiar variety of clay is termed *kaolin*. It is of the highest importance, because it forms, by fusion with silicate of potassa and lime, *porcelain* and *China*. When the clay and other ingredients used in pottery are not so pure and fine, the various kinds of *stoneware* and *earthenware* are formed. A porous clay, which has the property of drinking oil and grease into its capillary vessels, is extensively used for scouring woollens and cloths, under the name of *fuller's earth*.

GLASS.

When silica, obtained from quartz rock or pure white sand, is fused with alumina and the carbonates of potash and lime, a double silicate of potash and lime is formed, which is known under the name of *Bohemian* and *crown-glass*. The former can be submitted to intense heat without melting, and is therefore invaluable to the chemist in the combustion of organic bodies. The latter is combined with flint-glass to correct the chromatic aberration of lenses.

If soda is used instead of potash, a double silicate of soda and lime is formed; and this is familiar to us as *French plate*, and ordinary *window-glass*. The above silicates are mixed with clay and oxide of iron, when it is unnecessary to preserve the transparency of the glass; and in this manner wine-bottles, carboys, etc., are made.

Character of Alumina Salts.—They all have an alum-like taste; turn blue litmus-paper red; give an azure with *nitrate of cobalt* before the blowpipe, and a bulky gelatinous precipitate with *ammonia*.

Sym. Gl.   **GLUCINUM.**   Eq. 26.5

Discovered by Wöhler. It derives its name from γλυκύς, *sweet*, in allusion to the remarkable taste of its salts. When combined with silica and alumina it forms the beautiful green *beryl* and *emerald*.

Sym. Zr.   **ZIRCONIUM.**   Eq. 24.6.

Isolated by Berzelius. It occurs in nature as a silicate, forming *zircon* and the bright red *hyacinth*.

THORIUM (Th, 59.6), YTTRIUM (Y, 32.2), ERBIUM (Er, —), TERBIUM (Tb, —).

Thorium is remarkable as occurring in the form of a protoxide, ThO, forming the earth, *thoria*. It was discovered by Berzelius, in 1829, in a rare, black mineral named *thorite*, which is found in Norway.

Yttrium was found by Wöhler, and *Erbium* and *Terbium* by Mosander, 1843, in a mineral called *gadolinite*, which occurs at Ytterby, in Sweden.

CERIUM (Ce, 47.), LANTHANUM (Ln, 47), DIDYMIUM (Dy, 48).

The first of these rare metals was discovered by Klaproth, and the other two by Mosander, 1839, in *Cerite*. They are so little known that, until recently, they were all confounded together, under the name of Cerium.

Metals Lately Discovered by means of the Spectral Analysis.

Sym. Rb.   **RUBIDIUM.**   Eq. 85.

Bunsen and Kirchhoff, 1860.   Both *Rubidium* and *Cæsium* were originally found in the mother liquor of mineral waters; particularly of the salt-springs at Durkheimer. They have since been met with in a few minerals, as *lepidolite*.   Rubidium produces in the spectroscope two bright red lines beyond Fraunhofer's line A; and hence in a part of the spectrum usually invisible. (See plate facing page 123. Rb.)

Sym. Cs.   **CÆSIUM.**   Eq. 133.03.

Bunsen. Distinguished by two blue lines in the spectrum; which are of great intensity and sharpness of outline. (See plate facing page 123. Ce).

Sym. Tl.   **THALIUM.**   Eq. 204.

Crookes. Found in Lipari sulphur and pyritous ores. Gives a green lime in spectrum. (See plate, Tl.)

Sym. In.   **INDIUM.**   Eq. 37.07,

According to Reich and Richter; but 35.918 as given by a later authority. Found in Freiburg ores of arsenical pyrites, blende, and galena. Gives dark blue lines.

GROUP IV.

Metals whose Oxides form strong Bases.

Sym. Mn.   **MANGANESE.**   Eq. 27.67.

Discovered by Gahn, in 1774. Found principally in the state of black oxide, MnO_2, as *Pyrolusite*.

Preparation.—An artificial oxide is obtained by calcining

the carbonate in a well closed vessel. This is mixed with oil and ignited in a covered crucible, by which means the oil is converted into charcoal very intimately mixed with the oxide. The above process is repeated several times. The mixture is next made into a thick paste with oil and introduced into a crucible lined with charcoal, and filled in with charcoal-dust. This is then heated to redness, after which the cover is well luted down and the whole exposed for an hour and a half to the greatest heat of a wind furnace. The metal is found as a button at the bottom of the crucible.

Properties.— Manganese is a greyish white metal like cast-iron; oxidizes rapidly in the air; in water it evolves hydrogen. Sp. Gr. 8.013, 7.05, 6.850, and 7.0, according to different authorities.

Compounds with Oxygen.

Protoxide—MnO.

Forms the basis of the common salts of Mn. They are similar in form, or *isomorphous*, with those of magnesia and protoxide of zinc. They are neutral, and of a pale rose color.

Sesquioxide—Mn_2O_3.

Sources.—Braunite; and, as a hydrate, *manganite.*

Properties.—A feeble base, isomorphous with alumina and sesquioxide of iron.

Binoxide — MnO_2.

Sources.—Pyrolusite, psilomelane.

Uses. — When the materials employed in the manufacture of glass cantain prot-oxide of iron, this substance stains the glass green. To remove this stain, MnO_2 is added, which yields part of its oxygen to the iron, converting it into a sesquioxide, which has but little coloring effect, and being itself reduced to a sesquioxide, which is not a coloring body, although the deutoxide itself stains

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IRON. Eq. 28.

...in stones of *meteoric* origin; as an ore,
...ds.

...hite color, perfect lustre, highly mallea-
...tenacious of all metals; oxidizes in damp
...s water at a red heat; strongly mag-
...

...O.

Fig. 148.

...—Precipitates as a
...drate, when an al-
... any protosalt of

...Absorbs oxygen ra-
... ...ges to sesquioxide.
...ful base, and forms salts
...is with magnesia and ox-
...which have a pale green
...astringent taste.
...ite—Fe_2O_3.

...—Anhydrous, the *specu-
...re* and *red hæmatite*; as a hydrate, *brown*
...

...—Forms with acids, reddish salts of an acid
...on and astringent taste; with the more powerful
... it displays the part of an acid. Combines, for
...ple, with protoxide of iron to form black oxide, Fe_3
... FeO,Fe_2O_3. The black oxide also exists in nature
... *loadstone*, forming a valuable ore of iron, and a
...f magnetism. Fig. 148. Antidote for As.

8
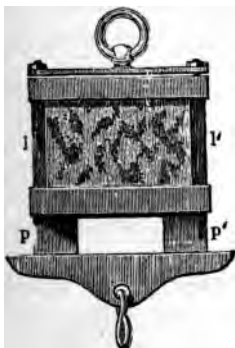
glass of a beautiful amethystine tint: it is this MnO_2 which colors the amethyst.

Mixed with acids, affords an excellent oxidizing agent; ignited, gives off one-third of its oxygen, leaving the *red oxide:* — $3MnO_2 = (MnO, Mn_2O_3) + 2O$; heated with concentrated sulphuric acid, it yields half its oxygen:— $MnO_2 + HO, SO_3 = MnO, SO_3 + HO + O$; extensively employed in manufacturing chlorine:—$MnO_2 + 2HCl = MnCl + 2HO + Cl$. It is largely used in making bleaching powder, 18,000 tons being annually consumed in England for this purpose alone.

Permanganic Acid—Mn_2O_7.

When manganate of potassa or *chameleon mineral*, KO, MnO_3, formed by heating equal weights of caustic potash and binoxide of manganese, is thrown into water, it first becomes green, then purple, and at last claret-colored; and a permanganate of potash, KO, Mn_2O_7, is formed.

Use. — As an oxidizing agent. If permanganate of potash be added to sulphuric or hydrochloric acid containing sulphurous acid in solution, the sulphurous acid is oxidized to sulphuric by the permanganate of potash, while the latter at the same time loses its color; it may therefore be employed to detect the sulphurous acid.

Sulphate of Manganese—$MnO, SO_3 + 7HO$.

Preparation.— Formed by heating the binoxide in sulphuric acid.

Use.—When cloths moistened with this salt are passed through a solution of bleaching-powder, an insoluble hydrate of the binoxide is thrown down upon the woollen or cotton fibre, and dyes it a permanent brown. Water and air test.

Character of the Salts of Manganese. — They have a pale rose color and an astringent taste. Before the blow-pipe they give, with *borax*, an amethystine bead in outer flame; with *carbonate of soda*, a bluish-green bead; with

hydrosulphate of ammonia, a flesh-colored precipitate; with the *alkalies* and their *carbonates*, give a white.

Sym. Fe.   **IRON.**   Eq. 28.

Sources.—Free in stones of *meteoric* origin ; as an ore, everywhere abounds.

Properties.—White color, perfect lustre, highly malleable, ductile; most tenacious of all metals; oxidizes in damp air, and decomposes water at a red heat; strongly magnetic.   Sp. Gr. 7.8.

Protoxide—FeO.

Preparation. — Precipitates as a white, bulky hydrate, when an alkali is added to any protosalt of iron.

Properties. — Absorbs oxygen rapidly, and changes to sesquioxide. It is a powerful base, and forms salts isomorphous with magnesia and oxide of zinc; which have a pale green color and an astringent taste.

Sesquioxide—Fe_2O_3.

Fig. 148.

Sources.—Anhydrous, the *specular iron ore* and *red hœmatite*; as a hydrate, *brown hœmatite.*

Properties.—Forms with acids, reddish salts of an acid reaction and astringent taste ; with the more powerful bases it displays the part of an acid.   Combines, for example, with protoxide of iron to form black oxide, $Fe_3O_4 = FeO,Fe_2O_3$.   The black oxide also exists in nature as the *loadstone,* forming a valuable ore of iron, and a source of magnetism.   Fig. 148.   Antidote for As.

18
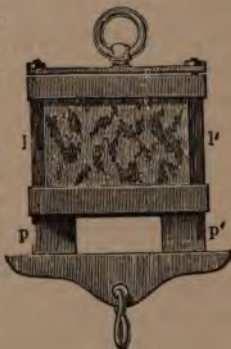
Ferric Acid—FeO_3.

Preparation. — By oxidizing sesquioxide of iron with nitre, at a red heat.

Properties.—Forms salts easily decomposed by organic matter; and, with the exception of Ferrate of Baryta, very unstable.

With *chlorine, iodine,* and *bromine,* iron forms proto and sesquisalts.

Sulphides of Iron.

Protosulphide—FeS.

Preparation. — Four parts of powdered sulphur are strongly heated with 7 parts of iron filings.

Uses.—It is a black, brittle substance employed in the laboratory as a source of sulphuretted hydrogen. $FeS + HO,SO_3 = FeO,SO_3 + HS$. When 60 parts of iron filings, 2 of sal ammoniac, and 1 of sulphur, all in powder, are made into a paste with water and applied immediately as a luting to iron vessels, it quickly sets as hard as iron itself, by the formation of a sulphide.

Bisulphide—FeS_2.

Sources. — Exists as *iron pyrites* or *fool's gold;* and appears in many cases to be derived from the deoxidation of sulphate of iron by organic matter. Combined with the protosulphide, forms *magnetic pyrites* ($2FeS,FeS_2$), and with arsenic, *arsenical pyrites* or *mispickel* (FeS_2,Fe As).

Use. — Under the name of *mundic,* iron pyrites is largely employed in the manufacture of sulphuric acid to afford sulphurous acid by ignition in the open air. Mispickel is roasted to form arsenious acid, AsO_3—the *white arsenic* of the shops.

Carbides of Iron.

White Cast-Iron is a compound of 4 equivalents of iron with 1 of carbon, Fe_4C. *Malleable* iron is cast-iron from

which nearly all the silicon and more than four per cent. of carbon has been burnt out by being—1st. Heated in contact with air—*refining.* 2nd. Heated with black oxide of iron—*puddling.* In this way but one-half per cent. of carbon is left in the purest bar-iron. *Steel* is malleable iron which has been heated to redness with charcoal for about 48 hours—*cementation.* It contains from 1.8 to 2.3 per cent. of carbon.

By Bessemer's process, malleable iron and steel are made from pig-iron *without the aid of fuel,* by causing hot air to pass through the liquid iron. The carbon is burnt away with the formation of carbonic oxide, and develops in its combustion sufficient heat to continue the operation without the assistance of external fire.

This process is conducted in a large iron vessel (Fig. 149)

Fig. 149.

called a "converter," capable in some cases of containing five tons of iron. Air is carried from condensing pumps into this vessel through the trunion A, whence it passes by a pipe, B, to the bottom, and so escapes into the melted iron within.

When the operation is finished, the molten steel is

poured out (by turning the converter over with appropriate machinery) and run into moulds. The quality of this steel is much improved by mixing with it, after conversion, a small amount of iron containing manganese.

In smelting, sulphides, nitrides, and phosphides of iron are formed in small quantities. They all have deleterious effects; sulphur rendering bar-iron *red short*, the others *cold short*.

Compounds of Protoxide of Iron.

Sulphate of Protoxide of Iron—FeO,SO_3+7Aq. Copperas, Green Vitriol.

Preparation.—Obtained by dissolving iron in dilute sulphuric acid, or by roasting iron pyrites, and exposing to air and moisture.

Properties.—Forms large green crystals, which slowly effloresce and absorb oxygen in the open air; forming a subsulphate of the sesquioxide. Combines with the sulphates of potassa and soda to form double sulphates isomorphous with those formed by the alkaline sulphates with sulphate of copper. (FeO,SO_3+KO,SO_3+6Aq) and (CuO,SO_3+NaO,SO_3+6Aq).

Uses.—As a reducing agent. It is, therefore, employed to precipitate gold and palladium from solution in the metallic state; and to *develop* photographs, by removing all the oxygen from the silver salt; thus, $3(AgO,NO_5) + 6(FeO,SO_3) = 2(Fe_2O_3,3SO_3) + Fe_2O_3,3NO_5 + 3Ag$. To form *Nordhausen* Sulphuric acid, it is first dried and then distilled at a red heat. The sesquioxide of iron which is left as a residue in this reaction, is sold as a polishing powder for glass and jewellers' ware, and as a red pigment, under the names of *colcothar*, *crocus of Mars*, and *rouge*.

Persulphate, or Sesquisulphate—$Fe_2O_3,3SO_3$.

Source.— Native in Chili, forming a white powder having the composition $Fe_2O_3,3SO_3 + 9Aq$.

Properties. — Forms double salts with the alkalies, re-

sembling common alum in form, composition, and taste. E. g. $NH_4O,SO_3 + Fe_2O_3, 3 SO_3 + 24 Aq$.

Note. — Salts of a metallic protoxide are frequently termed *-ous* salts, of a higher oxide *-ic* salts.

A ferrous and a ferric nitrate $(FeO,NO_5 + 6 Aq)$, and $(Fe_2O_3,3NO_5)$ may be formed, as well as a ferrous acetate, and a ferric oxalate; but they are not important.

Carbonate of Protoxide of Iron—FeO,CO_2.

Sources.—The two valuable ores, *spathic iron* and *clay iron-stone*, and ferruginous springs. The excess of carbonic acid in chalybeate springs holds the carbonate of iron in solution, and when the carbonic acid escapes, oxygen is absorbed from the air, and ochry hydrated sesquioxide of iron produced.

Tests.—Ferrous salts, with ferrocyanide of potassium, precipitate Turnbull's blue, with ferricyanide Prussian blue.

Ferric salts, with ferrocyanide of potassium, precipitate Prussian blue: this freshly prepared dissolves in a solution of oxalic acid, giving blue writing fluid. With sulphocyanide of potassium give a blood-red precipitate; with tincture of nut-galls form ink. (See page 251.)

Sym. Co. **COBALT.** Eq. 29.5.

Discovered by Brandt, in 1733.

Sources. — Tin-white cobalt, Co As, and *cobalt glance*, $CoS_2,CoAs$.

Properties.—Reddish-gray color; hard; brittle; almost as magnetic and infusible as iron. Slowly oxidizes in air. Not used in the metallic state, but in combination forms beautiful pigments. Sp. Gr. 8.5.

It has three oxides; the protoxide, CoO; sesquioxide, Co_2O_3; and cobaltic acid, Co_3O_5.

Uses. — *Zaffre*, used in enamel-painting, is an impure oxide of cobalt (made by roasting cobalt ore), mixed with

2 or 3 times its weight of sand. *Small* is a glass colored blue by oxide of cobalt. With alumina, oxide of cobalt forms *cobalt-ultramarine*, or *Thénard's blue ;* with oxide of zinc, *Rinman's green.*

Chloride of Cobalt — CoCl.

Preparation. — Formed by dissolving the oxide in hydrochloric acid, $CoO + HCl = CoCl,HO$.

Uses.—When writing is executed in dilute chloride of cobalt, the rose-red marks made by the hydrated chloride are so faint as to be invisible, but when the water is driven off by heating the paper, distinct lines are visible of anhydrous chloride of cobalt, and of the blue-color characteristic of this salt in its anhydrous state — *sympathetic ink.*

Tests.—With the alkalies, a blue precipitate; with their carbonates, a pink.

Sym. Ni.   NICKEL.   Eq. 29.6.

First recognized as a distinct metal by Cronstedt, in 1751.

Sources.—Associated with cobalt, to which it bears a close likeness, in meteorites, and various ores ; extracted from *kupfernickel*, Ni_2As, and *arsenical nickel*, NiAs.

Properties. — A white, hard, malleable, ductile, very tenacious, difficultly fusible metal. Strongly magnetic at temperatures below 630°. Oxidized by air at high temperatures. Most nickel compounds have a green color. An alloy of 51 parts of copper, 30.6 of zinc, and 18.4 of nickel, is highly prized for its malleability and silvery lustre, and is well known under the name of German silver. Sp. Gr. 8.8.

The *Oxides* of Nickel, NiO, and Ni_2O_3; its *sulphides*, NiS,Ni_2S, and NiS_2; *chloride*, NiCl; *sulphate* ($NiO,SO_3 + 7$ Aq), which forms with potassa and ammonia beauti-

ful double salts (NiO,SO_3 + KO,SO_4 + 6 HO) and
(NiO,SO_3 + NH_4O,SO_3 + 6 HO); and the various basic
carbonates of nickel have at present no industrial ap-
plication.

———

Sym. Cr.   **CHROMIUM.**   **Eq. 26.7.**

Discovered by Vauquelin, in *Vauquelinite*, chromate
of lead, in the year 1797.

Sources.— Chrome iron, FeO,Cr_2O_3.

Properties. — A dark-grey metal, possessing a strong
affinity for oxygen ; oxidizes in the open air below red
heat, and deoxidizes nitric acid with violence. Sp. Gr.
6.81.

Uses.—Not employed in the metallic state, but as an
oxide largely used in painting on porcelain, and in calico
printing.

Compounds with Oxygen.

These are 5 in number, and agree in composition and
properties with the corresponding ferric compounds ; the
protoxide, CrO, is a powerful base, forming pale-blue
salts ; the *sesquioxide*, Cr_2O_3, is a feeble base, and forms
poisonous green salts. It is not decomposed by heat, and
is, therefore, used to color enamel green. CrO,Cr_2O_3 cor-
responds to Magnetic Oxide of Iron ; CrO_3, *Chromic Acid*,
to Manganic and Ferric acids ; Cr_2O_7, to Permanganic acid.

Chromic Acid — CrO_3.

Preparation. — 100 measures of saturated solution of
bichromate of potassa are mixed with 150 measures of
sulphuric acid, $KO,2CrO_3$ + HO,SO_3 = KO,SO_3 + HO
+ $2CrO_3$.

Properties. — As thus made, chromic acid forms bright
red crystals, which are very deliquescent, and easily

decomposed into sesquioxide of chromium, by contact with organic matter. Hence its use as an oxidizing agent. It forms three classes of salts—basic, neutral, and acid. Of these the *bichromate of potassa*, $KO,2CrO_3$, is most important; it is used in dyeing, in the formation of aniline colors, and in photography. With logwood it makes a good ink; 3 oz. of solid extract of logwood are dissolved in 3 gallons of hot water; to this is added $\frac{1}{2}$ oz. of $KO,2CrO_3$, dissolved also in a little hot water. The ink is then ready for use. The *chromate of lead*, PbO, CrO_3, is the well-known *chrome-yellow*. *Subchromate of lead*, $2PbO,CrO_3$, which is formed by dipping the cloth moistened with chromate of lead into boiling milk of lime,

$$2(PbO,CrO_3)+CaO,HO = 2PbO,CrO_3+CaO,CrO_3 + HO,$$

is largely employed in dyeing.

Tests.—With *salts of lead*, the chromates give a yellow precipitate; with *nitrate of silver*, a red; with *subnitrate of mercury*, an orange.

Compounds with Chlorine.

Protochloride, $CrCl$, valuable as a reducing agent, owing to its intense affinity for oxygen, and the *Sesquichloride*, Cr_2Cl_3.

Sym. Zn.   **ZINC.**   Eq. 32.6.

Known in commerce since the time of Paracelsus, 1540.

Source.—The chief ores of Zinc, or, as it is called in commerce, *Spelter*, are the *Red Oxide*, ZnO, found at Franklin, New Jersey; *Blende*, ZnS, found in Cornwall and Cumberland, England, in Saxony, and throughout Missouri, Wisconsin, Iowa, etc.; *Smithsonite*, ZnO,CO_2, worked in Silesia, Belgium, and England; *Calamine*, a hydrated Silicate of Zinc, found in Carinthia and near Bethlehem, Pennsylvania.

Extraction from Ores.—First powdered, then roasted, to drive off sulphur or carbonic acid, $ZnS + 3O = ZnO + SO_2$; $ZnO,CO_2 = ZnO + CO_2$; and afterwards mixed with coke and distilled, $ZnO + C = Zn + CO$.

Properties.—Hard, bluish-white metal; brittle at ordinary temperatures, malleable and ductile between 200° and 300°, very brittle at higher temperatures; fuses at 773°; boils at 1904°, its vapor burning brilliantly on exposure to air. In a moist atmosphere Zinc is soon coated with oxide, which prevents a deeper oxidation and fits it for many industrial uses. Moistened with water Zinc combines at ordinary temperatures with chlorine, bromine, and iodine. Sp. Gr. 6.8 to 7.1.

Uses.—Metallic zinc is used for roofing, and as the oxidable metal in galvanic batteries. When sheet-iron is plunged into molten zinc and sal ammoniac the Oxide of Zinc is dissolved by the sal ammoniac as fast as formed, and the two metals are firmly united, forming *galvanized* iron. Brass is an alloy of 2 parts of copper and 1 of zinc. The Oxide of Zinc, ZnO, is sometimes substituted for white lead, under the name of *Zinc White*, but is not so opaque and dead-white; it is substituted for red lead in optical glass; in an impure state, as obtained from the flues of furnaces in which brass is melted, it is sold as *tutty*. Pure ZnO is prepared, as at Bethlehem, Pennsylvania, by roasting Zinc ores (such as the Silicate) in open fires and carefully collecting the white fumes passing off. Chloride of Zinc, ZnCl, when in solution, is employed as an antiseptic and as a preservative of wood. The double Chloride of Zinc and Ammonium ($NH_4Cl + ZnCl$) is employed to remove the oxide from Zinc, in the process of soldering.

Sulphate of Zinc—$ZnO,SO_3 + 7Aq$. White Vitriol is a powerful emetic; employed largely in calico printing.

Tests.—White precipitates with all the usual reagents.

Sym. Cd.   **CADMIUM.**   Eq. 56.

Discovered by Stromeyer, 1817.

Sources.—Accompanies the ores of zinc; *Greenockite*, CdS.

Properties.—Has a color and *cry* resembling tin; very soft, malleable and ductile; fuses at 442°; boils at 1580°; burns with salmon-colored fumes.   Sp. Gr. 8.6.

Uses.—Forms very fusible alloys; thus, 4 parts of Pb, 7 parts of Bi, 1.5 parts of Cd, and 2 parts of Sn form an alloy, fusing at 140° Fahr.   *Sulphide of Cadmium*, CdS, forms an excellent bright-yellow pigment; the *Iodide*, CdI, is employed by photographers to iodize collodion.

Test.—Yellow precipitate of Sulphide with Sulphuretted Hydrogen and Sulphide of Ammonium.

Sym. Cu.   **COPPER.**   Eq. 31.7.

Sources.—Found with cubic crystallization or massive at Lake Superior and in Siberia.   The Cornish mines afford *Copper Pyrites*, $Cu_2S + Fe_2S_3$.   From the Urals and from Australia come blue and green Carbonates, *Azurite* and *Malachite;* from Cuba red and black Oxides and Sulphides; from Chili a Chloride, *Atacamite.*

Properties.—Yellowish-red metal, hard, very malleable, ductile, and tenacious.   Fuses at 1996°; one of the best conductors of heat and electricity; burns in chlorine spontaneously, when in leaf form, and in oxygen at a moderate temperature.   Sp. Gr. 8.9.

Uses.—In coinage, alone or alloyed with nickel; sheathing of ships; in many pieces of mechanism; forms the negative element in Daniel's battery (Fig. 150, described page 98); alloyed with zinc forms *brass*, and, with different proportions of tin, *bronze*, *bell-metal*, *gun-metal*, and *spec-*

ulum-metal. The *Suboxide* of Copper, Cu_2O, is used to
stain glass a ruby
color; the *Black* Ox-
ide, CuO, communi-
cates a green color to
glass, and is used to
oxidize organic bodies
for purposes of analy-
sis. *Sulphate* of Cop-
per, *Blue Vitriol* (CuO,
SO_3+5Aq), is used in
calico printing and in
the manufacture of
cupreous pigments.

Fig. 150.

Tests.—Green color
in blowpipe flame;
pale blue precipitate
with *Ammonia*, dis-
solving with dark blue
color in excess of the
reagent; red with *Ferrocyanide of Potassium.*

Sym. Pb. **LEAD.** Eq. 103.7.

Sources.—Metallic Lead is rarely found native; gene-
rally occurs as Galena, PbS, which is worked extensively
in Cornwall and Cumberland, England, throughout Spain,
in Missouri, Illinois, Iowa, and Wisconsin. It is also
found combined with Oxygen, Selenium, and Tellurium;
with Arsenic and Antimony; with Carbonic, Phosphoric,
Arsenic, Vanadic, Chromic, Antimonic, Molybdic, and
Tungstic acids.

Extraction from Galena.—When Galena is roasted it ab-
sorbs Oxygen, and part is converted into Oxide of Lead with
evolution of Sulphurous acid, $PbS+3O=PbO+SO_2$, part
into Sulphate of Lead, $PbS+4O=PbO,SO_3$. When the
Sulphide and Sulphate thus formed come in contact with

fresh Galena in the furnace, they are both decomposed, with the formation of metallic Lead and Sulphurous acid, $2PbO + PbS = 3Pb + SO_2$ and $PbO,SO_3 + PbS = 2Pb + 2SO_2$.

Properties.—A soft, bluish-white metal, of small malleability, ductility, and tenacity; fuses at 620°, and crystallizes in cubes on cooling. Sp. Gr. 11.36. The high metallic lustre of freshly-cut lead is speedily lost by the formation of a superficial film of oxide on exposure to air; but the formation of this oxide is due to the combined action of air and moisture, *dry* air alone or *pure* water alone having no power to oxidize lead. All natural waters hold in solution air, uncombined carbonic acid, various chlorides, nitrates, and ammonia, all of which favor the corrosion of lead. But they also contain sulphates, phosphates, and carbonates, which generally counterbalance the action of the preceding substances; and thus free water contained in leaden cisterns, or conveyed to inhabitants of towns, through leaden pipes, may not hold an injurious amount of the poisonous Oxide of Lead.

Uses.— Metallic lead is but slightly affected even by boiling sulphuric acid, and is therefore employed in the sulphuric acid chambers. Since air and moisture only oxidize lead superficially, it is employed for cisterns, waters, gutters, roofing, etc. Lead, alloyed with about $\frac{1}{2}$ per cent of arsenic, to harden and granulate it, is the material of shot. When lead is alloyed with one-fourth its weight of Antimony it forms *type-metal*, which has the property of expanding on solidification, and thus copying a mould accurately. *Pewter*, *Britannia metal*, *fusible metal*, and the *soft solder* of tinsmiths are alloys of lead. Of the four Oxides of Lead, Pb_2O, PbO, PbO_2, and Pb_3O_4, the Protoxide, known as *Litharge* and *Massicot*, is used to increase the siccative property of drying oils. Dissolved in lime-water, it is used as a *hair-dye*: the lime partially decomposes the hair, and the lead of the oxide,

by combination with the sulphur of the hair, forms Sulphide of Lead, which stains the hair a permanent black. When litharge is roasted, at a temperature of 600°, it absorbs oxygen, and is converted into *Minium*, or *Red Lead*, Pb_3O_4, which is principally employed in the manufacture of flint-glass. A combination of the Chloride and Oxide of Lead ($PbCl,7PbO$) is used as a pigment, under the name of *Turner's yellow*. Its soluble salts form most delicate tests for Sulphuretted Hydrogen, which forms with them a black precipitate. This may be illustrated in an amusing manner as follows : We make a drawing on paper with a solution of Acetate or Nitrate of Lead, thickened so as to work well with a little gum. This drawing is of course invisible; but if the paper is dampened by sponging on the wrong side, and

Fig. 151.

exposed to HS, escaping from a tube, it is rapidly developed. Such a design as Fig. 151 is one well suited to this sort of "spiritual photograph."

Sym. Bi. **BISMUTH.** **Eq. 208.**

Discovered by Agricola in 1529.

Source.—Found native in quartz-rock in Saxony, Tran-

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sylvania, and Bohemia, from which it is extracted by fusion in iron tubes, placed in an inclined position, so as to allow the metal to flow out from the lower end.

Properties.—A hard, brittle, reddish-white metal, which fuses at 507°, and crystallizes on slow cooling in very obtuse rhombohedra. Oxidized by air at high temperatures; eagerly unites with Chlorine, Bromine, Iodine, and Sulphur. Sp. Gr. 9.79.

Uses.—The alloys of Bismuth with Tin and Lead melt easily, and on cooling expand greatly, for which reasons they are largely employed by die-sinkers, under the name of *fusible* metal, consisting of 5 parts of Bi, 3 of Pb and 2 of Sn. This will melt in boiling water. Some of its compounds are used as pigments, and the Subnitrate $(5PbO_3, 4NO_5+9HO)$ as a cosmetic and in medicine.

Test.—Yellow precipitate with Chromate of Potassa; soluble in Nitric acid.

Sym. U.   **URANIUM.**   **Eq. 60.**

Discovered by Klaproth, 1789, in *pitchblende* $(2UO, U_2O_3)$, which contains nearly 80 per cent. of the Black Oxide of Uranium.

Properties. — Steel-white color; slightly malleable; burns brilliantly in air at high temperatures; dissolved by Hydrochloric and Sulphuric acids, with the formation of a Protochloride, UCl, and a Sulphate, UO,SO_3, which is employed in giving a Canary color to glass, and has the remarkable power of rendering it fluorescent. (See pages 58 and 87.)

GROUP V.

Metals whose Oxides are Weak Bases, or Acids.

Sym. W. **TUNGSTEN.** Eq. 92.

Discovered by D'Elhugart, 1781.

Sources. — Found in *wolfram*, Tungstate of Iron, and Manganese $(MnO,WO_3,3FeO,WO_3)$, and *scheelite*, Tungstate of Lime (CaO,WO_3).

Properties.—A very hard, difficultly fusible metal, of an iron-gray color. Sp. Gr. 17.6.

Uses. — Tungstic acid, WO_3, is used in calico printing and as an anti-combustion mixture with starch, in the royal laundry of England.

Test. — Treated with Hydrochloric acid and digested with Zinc, yields a blue color.

———

Sym. V. **VANADIUM.** Eq. 68.46.

Discovered by Sefstrœm, 1830, in a Swedish iron ore from Taberg, but its principal ore is the Vanadate of Lead, found in Mexico and Chili.

Properties.—Vanadic acid is reduced by Potassium in a covered porcelain crucible, $VO_3+3K=3KO+V$.

Test.—When salts of Vanadic acid are mixed with tincture of galls they form a very black ink, ineffaceable by acids, alkalies, and even by chlorine.

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Sym. Mo. **MOLYBDENUM.** Eq. 47.88.

Discovered by Hjelm, 1780.

Source.—*Molybdenite*, MoS_2.

Preparation. — The ore is first roasted, $MoS_2+7O=MoO_3+2SO_2$, and the Molybdic acid so formed is made into

a paste with oil and charcoal, and exposed to a high heat
in a crucible lined with charcoal, $MoO_3 + 3C = Mo + 3CO$.

Properties.—White, brittle, and very difficult of fusion.
Sp. Gr. from 8.615 to 8.636.   Forms two basic oxides,
MoO and MoO_2, and a powerful metallic acid, MoO_3.

Test.—Purple precipitate with Terchloride of Gold.

———

Sym. Te.   **TELLURIUM.**   **Eq. 64.2.**

Discovered by Klaproth, 1795.

Sources.—Found in Transylvania, rarely native, gene-
rally as a Telluride of Gold, Silver, Bismuth, or Lead.

Properties.—Sp. Gr. 6.65.   Has the lustre of a metal,
but so closely resembles sulphur and selenium that it is
often classed among metalloids.

———

Sym. As.   **ARSENIC.**   **Eq. 75.**

Source.—Generally occurs as an alloy with iron, cobalt,
nickel, copper, or tin; also as an Arsenate of the above
metals, and, more rarely, in union with sulphur, forming
realgar, AsS_2, and orpiment, AsS_3.

Preparation. — When arsenical Sulphide of Iron, or
mispickel $(FeAs, FeS_2)$, is roasted it undergoes oxidation,
and its combined Arsenic is converted into Arsenious
acid, AsO_3.   The latter is conducted by the furnace-flues
into large chambers, where it condenses as a white mealy
powder.   By heating this acid with pulverized charcoal in
a Hessian crucible, upon the top of which a second cru-
cible has been luted, the reduced metal is sublimed as a
coating on the upper crucible.

Properties.—In its chemical properties Arsenic is nearly
allied to nitrogen and phosphorus, but, on account of its
brilliant steel-gray lustre, its high specific gravity, and its
facility in the conduction of electricity, it is here classed

among the metals. Heated to 356°, it gives off an oppressive garlicky vapor, which crystallizes on cooling in rhombohedra. Sp. Gr. 5.7 to 5.9.

Uses.—A small quantity of Arsenic is added to lead to produce a rounder shot. When partially oxidized by contact with moist air it is converted into *fly-powder*. Combined with Oxygen, as Arsenious acid, it forms several useful Arsenites. That of *Potash* has been long employed in medicine under the name of *Fowler's solution.* The Arsenite of Copper ($2CuO,AsO_3$) is the delicate *Scheele's green.* The double salt of Acetate and Arsenite of Copper—$CuO,C_4H_3O_3 + 3(CuO,AsO_3)$—is also used as pigment, and is known as *Schweinfurt green.* Arsenious acid (known in commerce as *Arsenic* or *ratsbane*) is moreover employed to prevent smut in grain, and as a *soap for glass,* by converting the Protoxide of Iron, which stains the glass green, into a harmless sesquioxide.

Arsenic Acid, AsO_5, prepared by oxidizing Arsenious acid with Nitric acid, has been employed as a substitute for tartaric and phosphoric acids in calico printing, but its use is attended with the same danger of poisoning to the workmen employed as there is in every other application of Arsenic and its compounds.

The Bisulphide of Arsenic (realgar), AsS_2, is an ingredient of the signal-light known as white Indian fire, and the Tersulphide (orpiment) is mixed with Arsenious acid to form *King's yellow.*

Tests.—Before the blowpipe evolves a peculiar odor of garlic; with ammonio-nitrate of silver, AsO_3 gives a yellow precipitate, AsO_5 a dull red; with ammonio-nitrate of copper AsO_3 gives a green precipitate.

Detection of Arsenic.

Marsh's Test.—In a hydrogen generator, of the form indicated (Fig. 152), introduce some of the suspected sub-

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Fig. 152.
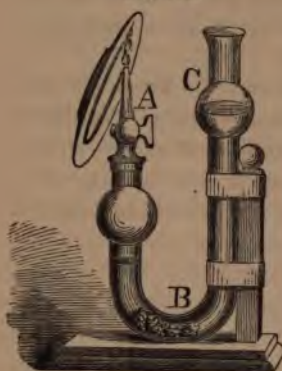
stance. If Arsenic be present, a glass or porcelain plate, held in the burning jet of hydrogen, will be coated with a metallic mirror of Arsenic.

Reinsch's Test.—Boil the suspected liquid, acidified by one-tenth its bulk of Hydrochloric acid, for half an hour with bright copper foil. The reduced Arsenic will be deposited as gray metallic crust of Arsenide of Copper.

Sym. Ti.   **TITANIUM.**   Eq. 24.33.

Discovered by Klaproth, 1795.

Sources.—*Ilmenite* (FeO, TiO_2) and *rutile, brookite* and *anatase*, which are nearly pure Titanic acid, TiO_2, occurring under different crystalline forms. Copper-colored cubes, consisting of Cyanide and Nitride of Titanium are frequently found in iron slags.

Uses.—The Oxide of Titanium is employed in painting porcelain and in coloring artificial teeth.

Sym. Sn.   **TIN.**   Eq. 58.

Sources.—The only important ore is *Tin-stone*, SnO_2.

Extraction.—After the ore has been roasted and washed it is mixed with one-fifth its weight of charcoal, and with a little lime, as a flux to the flinty gangue, and reduced by intense heat in a reverberatory furnace.

Properties.—A very malleable, brilliant, white metal, which fuses at 442°. Sp. Gr. 7.29. When a bar of Tin is bent it gives out a peculiar sound, called the *cry* of Tin.

Burns brilliantly in air at high temperatures, forming the Binoxide, SnO_2.

Uses.—When molten Tin is poured upon the surface of sheet-iron or copper it forms a superficial coating of alloy, and the iron or copper so coated is extensively employed under the name of *Tin-plate*. The many alloys of Tin have previously been described under bismuth, copper, and zinc. An *amalgam* of Tin is employed for silvering mirrors.

Neither the Protoxide, SnO, nor the Anhydrous Binoxide of Tin, SnO_2, are employed in the arts; but when the Binoxide is combined with water it undergoes a remarkable change of properties, and forms two acids, Metastannic acid ($Sn_5O_{10},10HO$), which is largely employed in whitening enamels, and, under the name of *putty powder*, for polishing plate, and Stannic acid (HO,SnO_2), which forms in combination with soda, as Stannate of Soda (NaO,SnO_2+4Aq), a much-used mordant. Of the three Sulphides of Tin, SnS,Sn_2S_3 and SnS_2, the last is employed, under the name of *mosaic gold*, in imitating bronze, and with electrical machines.

Sym. Sb.   **ANTIMONY.**   **Eq. 120.3.**

Discovered by Basil Valentine, at the end of the thirteenth century.

Sources. — Sometimes found native, frequently as an alloy with other metals; but always extracted from the tersulphide of antimony—*grey* antimony ore SbS_3.

Properties. — A brilliant, bluish-white, brittle metal, which fuses at 840°. Sp. Gr. 6.715.

Uses. — The most important alloy of antimony is *typemetal;* which consists of 100 parts of lead and 20 of antimony and 5 of tin. For stereotyping, Pb 100, Sb 18, Sn 5.

Compounds.—Antimony combines with both three and

five equivalents of oxygen, sulphur, and chlorine. When combined with potassa and tartaric acid, the teroxide, SbO_3, forms tartar emetic $(KO,SbO_3,\overline{T})$; ground with linseed-oil, it is employed as a substitute for white lead. When an alloy of zinc and antimony is dissolved in dilute sulphuric acid, the hydrogen set free from the water of the sulphuric acid unites, while in a nascent state, with antimony, to form antimoniuretted hydrogen. $Zn_3Sb+3(HO, SO_3)=3(ZnO,SO_3)+SbH_3$.

Test. — The salts of antimony give an orange-red precipitate of tersulphide, with sulphuretted hydrogen.

Sym. Ta.   **TANTALUM.**   Eq. 68.72

Discovered by Ekeberg, in *yttrotantalite* from Sweden, 1802.

Sym. Cb.   **COLUMBIUM.**   Eq. 68.8.

Found by Hatchett, in a black mineral from Massachusetts named *columbite*, in 1801.

GROUP VI.

Noble Metals reduced from their Oxides by Heat alone.

Sym. Hg.   **MERCURY.**   Eq. 100.

Sources.—Occasionally found in the metallic state, but generally combined with sulphur, forming cinnabar HgS. By heating, cinnabar gives off its sulphur as sulphurous acid, and its mercury as a vapor, which is collected in condensing chambers.

Properties. — Mercury is the only metal which is fluid at ordinary temperatures. It freezes at —39°, and boils at 662°. Heated in the air to 650°, it is converted into the red oxide; with chlorine, bromine, and many metals, it

combines at ordinary temperatures; and also with sulphur and iodine, if triturated with them.   Sp. Gr. 13.5.

Uses. — Largely employed to form an amalgam with silver and gold, in order to extract them from their ores; in the construction of thermometers, barometers, etc; as a medicine; as an amalgam with tin in silvering mirrors.

Compounds. — Oxygen, sulphur, chlorine, bromine, and iodine unite with both one and two equivalents of mercury. Of the compounds so formed, HgS is known as the valuable pigment *vermilion;* Hg_2Cl, Subchloride of Mercury, and $HgCl$, are known in medicine under the names of *calomel* and *corrosive sublimate*; the Bromides and Iodides of mercury are employed in photography.

Tests. — With iodide of potassium, a precipitate first yellow, then red; silver-like deposit on copper foil.

Sym. Ag.   **SILVER.**   Eq. 1.08.

Sources. — Found native, and as a chloride; but principally obtained from its sulphide, AgS.   The latter is frequently associated with lead to form *argentiferous galena.*

Uses. — For coins and domestic utensils, and (as a coating to less valuable metals) in plated ware.

Photography. — A thin organic film, as of collodion, spread upon glass, and charged with iodide, bromide, and free nitrate of silver, suffers a change under the influence of light by which it acquires the power of reacting with certain solutions called developers, so as to produce an opaque insoluble body.   By applying this property, negative pictures are produced in the camera.   Chloride of silver, in contact with organic matter, blackens by mere exposure to light, and to this fact we owe the production of *positive* pictures on paper from the *negatives* taken in the camera.

Nitrate of silver thickened with gum Arabic and colored by India-ink is used for marking linen indelibly.   The linen

is first moistened with a solution of soda, which precipitates the oxide of silver upon the fibre of the goods. Under the name of Lunar caustic it is used as an escharotic.

Test. — Hydrochloric acid or a soluble chloride, precipitates a dense white cloud of chloride of silver, quickly changing to violet by exposure to the light.

Sym. Au.   GOLD.   Eq. 197.

Sources. — Found crystallized in cubes or octahedra, or in masses called *nuggets.*

Properties. — Most malleable of metals; one of the best conductors of heat and electricity; fuses at 2016°. Unaffected by any of the acids alone, but dissolved by a mixture of 1 part of nitric acid with 4 parts of hydrochloric acid—*aqua regia.* Sp. Gr. 19.34.

Uses. — In the state of powder, in painting porcelain, etc. Alloyed with copper, it is sufficiently hard for jewellers'-ware and coin. Employed to color glass a deep red. The cyanide of gold and potassium is used for electro-gilding.

Test. — A mixture of protochloride and bichloride of tin precipitates from salts of gold the Purple of Cassius; oxalic acid with heat a brown precipitate of metallic gold.

Sym. Pt.   PLATINUM.   Eq. 98.7.

Sources. — Platinum, Palladium, Rhodium, Osmium, and Iridium are generally found associated together in the form of coarsely rounded grains.

Properties. — Very lustrous, ductile, tenacious, white metal, fusible only by the voltaic battery or oxyhydrogen blowpipe. Sp. Gr. 21.5.

Uses — Owing to its infusibility, and its power of resisting alkalies, and other chemical reagents, platinum is largely employed as the material of crucibles and stills. Those intended for the concentration of sulphuric acid sometimes weigh upwards of 1000 ounces. By ignition of the double chloride of platinum and ammonium, metallic platinum

may be obtained in a very finely divided state, known as *platinum sponge*. This substance has a very strong adhesion for gases; and it will condense a mixture of them to such an extent as to cause a chemical combination. Thus, if a jet of hydrogen is directed upon a piece of this substance in the air, the union of the H with O from the air, will be so energetic as first to heat the Platinum sponge red-hot, and then ignite the hydrogen jet. This action is applied to the useful purpose of procuring a light rapidly, in Döbereiner's lamp (Fig. 153). The jet of hydrogen, when turned on, heats the platinum sponge in the little box, f, is itself ignited, and so serves to light a taper, or the like.

Fig. 153.

Even massive platinum possesses a like power. Thus a wire of this metal coiled over the wick of a spirit-lamp, as in Fig. 154, will continue to glow by causing a slow combustion of the alcoholic vapor after the flame has been extinguished. This is called the "flameless lamp."

Fig. 154.

Sym. Pd. **PALLADIUM.** Eq. 53.3.

Discovered by Wollaston, 1803.

Sources.—Forms from one-third to one per cent. of platinum ores.

Properties. — A hard, ductile, white metal, very difficult of fusion. Sp. Gr. 11.4.

Uses. — For graduated scales, and as an alloy with silver, it is employed by dentists.

Sym. Ir.   **IRIDIUM.**   **Eq. 99.**

Descatils and Tenant, 1804.   Sp. Gr. 21.15.

Properties. — Very brittle, hard, white metal, fusible only by the oxyhydrogen blowpipe, and voltaic current. It is the heaviest of elements.   Alloyed with osmium, as *iridosmine*, it is used for pointing pens.   Its salts assume, when in solution, beautiful colors, from which property, the name iridium (from Iris, the rainbow) is derived.

Sym. Os.   **OSMIUM.**   **Eq. 99.6.**

Tenant, 1803.   Sp. Gr. 21.4.

Properties.—A white, very brittle metal.   It forms no less than five compounds with oxygen, and four with chlorine.

Sym. Ru.   **RUTHENIUM.**   **Eq. 52.2.**

Klaws, 1845.   Sp. Gr. 11.2.   Most infusible of metals.

Sym. Rh.   **RHODIUM.**   **Eq. 52.2.**

Wollaston, 1804.   Sp. Gr. 12.1.   A white, very hard metal, scarcely fusible before the oxyhydrogen blowpipe.

ORGANIC CHEMISTRY.

Organic Chemistry treats of those *organized bodies* which have been formed under the influence of the vital force, and of the *organic compounds* which can be derived from organized bodies by the action of chemical reagents.

Both classes of substances above referred to, are distinguished from inorganic substances in several ways:

1st. The mass of organic bodies consists of only six, out

of the sixty-four elements; viz., carbon, hydrogen, oxygen, nitrogen, and, to a lesser extent, sulphur and phosphorus.

2nd. But carbon, hydrogen, oxygen, and nitrogen, combine in so many, and such high proportions, that they alone, form a vastly greater number of bodies than is met with in inorganic chemistry.

3rd. While inorganic compounds are formed by the *pairing* together of elements, or of binaries, or of ternaries, with each other to form substances possessed of a certain symmetry of constitution, no such regularity is observable in organic chemistry.

4th. Natural affinities seem often to be overruled by vital force, and organic compounds are formed in opposition to the ordinary laws of chemistry.

5th. It thus happens that organized bodies are comparatively unstable, and prone to decomposition after the vital force, which created them, has ceased to act.

6th. One element may frequently be *substituted* for another, without altering the essential characteristics of an organic compound.

The substances met with in organic chemistry are most conveniently treated of under the following heads:

I. *Saccharine and Amylaceous Bodies.* — Mostly nutritious substances with feeble affinities. They are composed of 24 equivalents of carbon, united with different proportions of oxygen and hydrogen. From them are derived the Alcohols and Ethers.

II. *Ethyl, Methyl, etc.*—Compound radicals resembling in their chemical relations hydrogen and the metals.

III. *Vegetable Acids.*

IV. *Vegetable Bases:*

(*a*) Those found in nature.

(*b*) Those formed artificially.

V. *Oils:*

(*a*) Fixed Oils or Fats.

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(*b*) Essential or Volatile Oils.

VI. *Cyanogen* — a compound radical which resembles chlorine in its relations — and its compounds.

VII. *Organic Coloring-Principles.*

VIII. *Albuminous Bodies.*

I. SACCHARINE AND AMYLACEOUS BODIES.

1. Starch — $C_{24}H_{20}O_{20}$.

Sources. — The grains, roots, and stems of plants. It occurs in small, rounded grains, which vary greatly in size and appearance. Those of the *tous les mois* are about $\frac{1}{290}$ of an inch in diameter; and those of wheat, $\frac{1}{1000}$th. Each grain is inclosed in a thin envelope, which is unaffected by cold water, but ruptured by the expansion of the starchy matter, on applying heat.

Figure 155 represents some starch grains of the potato, as seen under the microscope, by ordinary light.

Fig. 155.   Fig. 156.   Fig. 157.

Figure 156 shows the appearance of the same, when viewed by polarized light, as indicated in pages 65 and 66, a black cross being here developed on each grain.

Figure 157 shows one of these grains, after it has been boiled, as viewed under a powerful microscope.

Preparations. — In order to free the starch granules from gluten and other substances contained in the seeds,

the latter, after being mashed, are washed upon a cloth sieve with water; the gluten remains behind.

Properties.—An insipid, white solid, insoluble in cold, but slightly soluble in boiling water. By exposure for a length of time to a temperature of 400°, by gentle heating in acidulated water, or by the action of *diastase* — a nitrogenized body formed from the gluten of germinating seeds — starch undergoes a peculiar change, and the substance so formed, and which is known under the name of Dextrine or British Gum, is capable of solution in cold water. It is employed in the manufacture of envelopes, for dressing chintzes, and other cotton goods, in the fastening of mordants, etc.

Arrow-root, tapioca, and sago, are varieties of starch.

Test. — Iodine forms a beautiful blue compound with starch, which is insoluble.

2. Gum — $C_{24}H_{20}O_{20}$.

A term applied to a number of substances which exude from the bark of trees, and form glassy, tasteless, and inodorous masses, generally of a globular form. Dissolved in water, they form *mucilage*, which is used as a substitute for paste. Gum Arabic, Gum Senegal, and Gum Tragacanth, are the important varieties.

By boiling with Sulphuric acid, Gum Arabic yields sugar —with nitric acid, *mucic* acid.

3. Lignine — $C_{24}H_{20}O_{20}$.

Modifications.—Woody Fibre; Cellulose.

Sources. — Found under many modifications: sometimes it can be used as food; as the pulp of roots, esculent plants; at others it is indigestible; wood; shells of nuts: it is light and porous in elder pith or cork; soft and pliable in hemp and cotton fibre. Fig. 158 shows Lignine of wood, as seen under the microscope.

Properties.—Tasteless, insoluble in water and alcohol, and incapable of nutrition. At low temperatures, strong oil of vitriol converts it into *dextrine*, and finally into *glucose*. It is not colored by iodine.

Fig. 158.

By the action of equal parts of the strongest nitric and sulphuric acids, it is changed into a very explosive body, *gun-cotton*, or *pyroxyline*. It has two modifications; the one, explosive, is insoluble in a mixture of alcohol and ether; the other is readily soluble, negative cotton. The latter is largely employed in preparing photographic plates, and in surgery. This change is not well understood, but it is supposed that the elements of Hyponitric acid are substituted for several equivalents of hydrogen; thus, to form gun-cotton, $C_{24}H_{20}O_{20} + 4NO_5 = C_{24}H_{16}(NO_4)_4O_{20} + 4HO$; to form negative cotton, $C_{24}H_{20}O_{20} + 6NO_5 = C_{24}H_{14}(NO_4)_6O_{20} + 6HO$.

By acting on starch, grape-sugar, mannite, gum, and dextrine, with nitric acid of specific gravity 1.5, they are converted into a transparent, colorless jelly, known as *xyloidin.* Paper so treated acquires the appearance of parchment, and great combustibility.

When wood is kept in dry air or under water it undergoes no change, but exposed to air, in presence of moisture, it absorbs oxygen, and experiences a slow decay, *eremacausis*, with the evolution of carbonic acid and water. The fertility of the soil depends in great measure upon the presence of decaying vegetable matter—*humus, geine, ulmine*—and the constant liberation of carbonic acid and water.

When vegetable matter, such as aquatic and herbaceous plants, decay in marshy soils, *peat* is first formed, and afterwards, by the heat developed during decomposition, and by pressure changed into *lignite*, and finally

into *coal*. Bituminous substances, like naphtha, petroleum, asphaltum, etc., have probably been formed from plants or marine animals by slow decay under water.

When wood is subjected to destructive distillation it gives off illuminating gas and many other hydrocarbons, along with *water, acetic pyroligneous* acids, creosote, pyroxylic spirit, tar, etc.

Creosote—$C_{28}H_{16}O_4$. A colorless, oily, transparent liquid, which boils at 397°. It has a burning taste and a smell like burned meat. It is highly antiseptic, and it is owing to the presence of Creosote in tar, smoke, and pyroligneous acid that these substances have preservative properties. Used both internally and externally in medicine.

When tar is distilled, a light and heavy oil passes over and a hard residuum, *pitch*, remains. The principal constituent of the light oil is *Eupione*, C_5H_6, of the heavy oil, *Paraffine*, $C_{20}H_{21}$.

Paraffine is a tasteless, inodorous, white solid. It is insoluble in water, but dissolves freely in ether and oils. In consequence of its perfect indifference to the strongest alkalies and acids, it has derived its name from the two Latin words *parum* and *affinis*, "without connection."

On distilling bituminous coal, *illuminating gas* (which consists mainly of light and heavy carburetted hydrogen), carbonic acid, sulphuretted hydrogen, salts of ammonia, etc., and a viscid, resinous liquid, called *coal-tar*, are formed.

Coal-tar yields on distillation a very volatile, inflammable oil, which has been largely employed in Germany, France, England, and in this country, before the discovery of petroleum, for illuminating purposes. It has likewise been used extensively as a solvent for caoutchouc, in the manufacture of water-proof goods.

This coal-tar oil is found, by treatment with acids and

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alkalies, to contain three classes of bodies: 1st. Substances having a basic reaction, *picoline, aniline,* and *leucoline;* 2nd. Acids, of which the most important is *carbolic acid,* or *phenol;* and 3rd. Neutral Hydrocarbons, some of which are liquid, as *toluol, cymol, benzol,* and others solid, as *naphthalin* and *paranaphthalin.*

Naphthalin, $C_{20}H_8$, separates in colorless, crystalline plates from the oil which comes over last in the distillation of coal. It melts at 176°, boils at 413°, and, heated to a still higher point, burns with a red, smoky flame. It has the same composition as paranaphthalin, from which it mainly differs in being freely soluble in alcohol.

4. Sugars.

There are several varieties of sugar, all of which are sweet to the taste, soluble in water, and convertible into alcohol by fermentation. The most important are :—

1st. **Cane-sugar—**$C_{24}H_{22}O_{22}$.

Sources. — Chiefly obtained from the sugar-cane; also found in the sap of the sugar-maple, in the juices of the beet and other roots, and the stalks of Indian-corn.

Preparation.—After its juices have been expressed from the plant, they are evaporated to a thick syrup, from which the sugar crystallizes on cooling. What remains is *treacle,* or *molasses.*

Properties.—White, inodorous, very sweet, and soluble; by slow evaporation it may be made to crystallize in prisms—*rock-candy.* It melts at 356°, and forms, on cooling, *barley*-sugar; at a temperature of 420°, it gives up four atoms of water, and is converted into *caramel,* $C_{24}H_{18}O_{18}$.

2nd. **Grape-sugar—**$C_{24}H_{28}O_{28}$. Glucose.

Sources. — Grapes, many other sweet fruits, and the solid part of honey.

Preparation. — The juice of grapes is first freed from

acid by neutralizing it with chalk, then boiled down to a syrup, clarified, and crystallized. Also prepared by conversion of starch or lignine, page 232.

Properties.—Not by any means as sweet or soluble as cane-sugar.

Test.—Grape-sugar instantly precipitates suboxide of copper, from a boiling solution of sulphate of copper containing potassa, while cane-sugar slowly affects it.

FERMENTATION.

This term is applied to a decomposition of an organic body, resulting from the decomposing force exerted by another organic substance, called a *ferment*, which is itself in process of decomposition. The molecular movement that is taking place among the particles of the ferment appears to be communicated to the fermentable substances with which it is in contact, and causes them to break up into their simpler constituents.

There are many ferments: *yeast* (which is the frothy matter that forms on beer and other liquids in process of fermentation), *blood, albumen, caseine,* and *juices* of many plants, and other putrescent matters. They all contain nitrogen, and derive from it their peculiar proneness to decomposition. So likewise there are several kinds of fermentation, distinguished as the

(*a*) Lactic.—When putrid cheese is mixed with water and sugar, the caseine contained in the former substance produces fermentation, and the sugar is converted into *Lactic acid,* $C_6H_5O_5,HO$, carbonic acid, and water.

(*b*) Butyric.—If this fermentation is allowed to proceed, the lactic acid disappears and *Butyric acid* ($C_8H_7O_3,HO$) is found in its place; thus, $C_{24}H_{28}O_{28}=4HO+8H+8CO_2+2(C_8H_7O_3,HO)$.

(*c*) Viscous.—So also, when the juice of beets is exposed to a temperature of 100° for some time, in contact

with air, it is converted into lactic acid and a viscous mucilaginous substance resembling gum Arabic.

(*d*) **Vinous** or **Alcoholic.**—Pure grape-sugar undergoes no change in or out of contact with air, but when mixed with yeast it is rapidly converted into water, carbonic acid, and alcohol, C_4H_5O,HO; thus, $C_{24}H_{28}O_{28}=4HO+8CO_2+4(C_4H_5O,HO)$.

Alcohols and their Derivatives.

1. *Wine-Alcohol.*

(*a*) Ether.　Action of acid on alcohol.

(*b*) Aldehyde, Acetal, Acetic Acid, and Acetone.　Action of oxygen on alcohol.

(*c*) Chloral, Mercaptan.　Action of chlorine and sulphur on alcohol.

2. *Methylic Alcohol; Wood Spirit.*

(*a*) Wood-ether.

(*b*) Formic Acid.

3. *Propylic, Butylic,* and *Amylic Alcohol;* their homologues and derivatives.

1. **Wine-Alcohol** — C_4H_5O,HO.　The alcohol obtained by fermentation, as above described, is very dilute.　By successive distillations, however, it may be *rectified* until it contains but 10 per cent. of water.　To obtain *absolute* or pure alcohol, common alcohol must be thoroughly mixed with half its weight of quicklime, and the spirit distilled from the mixture by the heat of a water-bath.

Properties.—Pure alcohol is a limpid, colorless liquid, of a penetrating smell and agreeable taste.　Its specific gravity at 60° is 0.794.　It boils at 173°, giving off a vapor which is very inflammable, and burning with a pale, smokeless, hot flame.　It has never been frozen, but at a temperature of —146° becomes thick and tenacious, like melted wax.　In solvent powers, it is inferior to water only, and dissolves many substances totally insoluble in

water, like the resins. Not only is a great number of vegetable bodies, like the alkaloids, essential oils, etc., soluble in alcohol, but also the mineral alkalies and many salts. The process of malting, brewing, and bread-making depend upon the formation of alcohol.

(a) Ether—C_4H_5O.

Preparation.—A mixture is made of 8 parts by weight of concentrated Sulphuric acid and 5 parts of Alcohol, of sp. gr. 0.834, and heated in flask A. When its temper-

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ature has risen to 300°, the heat is regulated so as constantly to maintain that temperature. Under these circumstances Alcohol and Sulphuric acid combine, and the Sulpho-vinic acid thus formed is afterwards decomposed into Sulphuric acid and Ether, $C_4H_5O,HO+2(HO,SO_3)=$ $(C_4H_5O,2SO_3,HO)+HO)$ and $(C_4H_5O,2SO_3,HO)+HO=$ $C_4H_5O+2(HO,SO_3)$. The Ether and water vapor condense into the inner tube, around which cold water is kept flowing (in at d and out at g), and are collected in a vessel placed at its lower end. The process may be made

continuous, if alcohol is supplied to A; for the acid serves merely to break up the alcohol which is constantly flowing into the flask, and at the end of the operation remains behind, while the ether distills over into the condenser.

Properties.—Owing to its mode of formation, commercial Ether thus obtained is termed Sulphuric Ether. It is a colorless, limpid liquid, of fragrant, intoxicating odor, and pungent taste. At 60° its density is 0.72; it boils at 96°, and remains liquid under the severest cold. Ether dissolves phosphorus, a few salts, most oils and fats, and some other organic compounds. When exposed to air, Ether absorbs oxygen and is converted into Acetic acid, $C_4H_3O_3,HO$. Transmitted through a red-hot tube, it is resolved into light and heavy Carburetted Hydrogen and Aldehyde, C_4H_3O,HO. Its vapor, when inhaled with air, produces insensibility to pain.

(*b*) Products of the Oxidation of Alcohol.

Aldehyde is a thin, colorless fluid, of a suffocating, ethereal odor; density 0.792; boiling point 72°; and burns with a pale flame. It is soluble in water, alcohol, and ether; dissolves sulphur, phosphorus, and iodine, and has such an affinity for oxygen that it reduces many metallic salts.

Acetal, $C_{12}H_{14}O_4$, is a colorless liquid, formed by the slow action of moistened platinum black, upon the vapor of alcohol diffused through a bell-glass, to which air has free access. By prolonging the action of platinum black, Acetal absorbs still more oxygen, and is converted first into aldehyde, and finally into acetic acid.

Acetic Acid, $C_4H_3O_3,HO$, is manufactured in Germany by causing a mixture of dilute alcohol and yeast to flow over wood-shavings, which are exposed in a current of air in a cask pierced with holes. The best vinegar, however, is made by the natural souring of wine when exposed to the air, $C_4H_5O,HO+4O=C_4H_3O_3,HO+2HO$. Pyrolig-

neous acid, formed by distilling wood in close vessels, is a very impure acetic acid, which is extensively employed in calico printing.

Properties.—When concentrated it is a colorless liquid, of a pleasant, penetrating odor, and extremely sour taste. It boils at 240°, giving off inflammable vapor; cooled below 60°, it solidifies in large transparent crystals; at 60° its density is 1.06. It readily mixes with water, alcohol, and ether, and dissolves camphor and several resins. All the Acetates are soluble. The most important are:—

Acetate of Lead, $PbO,C_4H_3O_3+3HO$, Sugar of Lead is formed by dissolving Litharge in Acetic acid. It is a powerful poison. Employed in analysis, and externally in medicine. Besides this neutral salt, there are various basic Acetates, as $2PbO,3C_4H_3O_3$ and $3PbO,C_4H_3O_3+HO$. The latter crystallizes in needles, from a solution of 7 parts of litharge and 10 parts of sugar of lead digested in 30 parts of water. It is used in the proximate analysis of organic compounds and in pharmacy under the name of *Goulard's Extract of Lead.*

Acetate of Copper, $CuO,C_4H_3O_3+HO$, Distilled Verdigris is obtained in dark-green crystals from a filtered solution of verdigris in hot acetic acid. It is used as a pigment. Verdigris is a mixture of subacetates, procured by covering copper plates with pyroligneous acid or the refuse of grapes in wine-making.

Acetate of Alumina, $Al_2O_3,3(C_4H_3O_3)$, is obtained by decomposing a solution of Sugar of Lead by Alum. Used as a mordant.

Chloracetic Acid, $C_4Cl_3O_3,HO$, is formed by exposing crystals of Acetic acid, placed under a bell-jar filled with chlorine, to the direct rays of the sun. Three atoms of Hydrogen are replaced by 3 atoms of Chlorine; thus, $C_4H_3O_3,HO+6Cl=C_4Cl_3O_3,HO+3HCl$. It closely resembles acetic acid, and forms analogous chloracetates.

Acetone, C_3H_3O, *Pyroacetic Acid* is an inflammable

liquid obtained by destructive distillation of metallic acetates; thus, $2(PbO,C_4H_3O_3)=2PbO+2(C_2H_3O)+2CO_2$.

(c) Action of Chlorine and Sulphur on Alcohol.

Chloral — $C_4HCl_3O_2$. When dry chlorine is passed into absolute alcohol, aldehyde is first formed, and hydrochloric acid. By continuing the process, still more hydrogen is replaced by chlorine, and at last chloral is formed; thus, $C_4H_6O_2+2Cl=C_4H_4O_2+2HCl$, and $C_4H_4O_2$ $+6Cl=C_4HCl_3O_2+3HCl$. It is an oily liquid, of a peculiar odor, which brings tears to the eyes, specific gravity 1.5, and boils at 201°. Bromine is likewise absorbed by alcohol, to form *bromal*, $C_4HBr_3O_2$, and both are decomposed by caustic alkalies, with the production of a formate of the base, and chloroform or bromoform; thus, $KO,HO+C_4HCl_3O_2=KO,C_2HO_3+C_2HCl_3$.

In like manner by the action of chlorine on light hydrochloric ether, C_4H_5Cl, one atom of hydrogen after another may successively be replaced by chlorine, until finally in the fifth distinct compound thus formed, sesquichloride of carbon, C_4Cl_6, no hydrogen remains.

Mercaptan — $C_4H_6S_2$, is a limpid liquid obtained by replacing, not the hydrogen in alcohol, but oxygen, with its congener, sulphur.

2. Methylic Alcohol—$C_2H_4O_2=C_2H_3O,HO$.

Preparation.—Wood-vinegar, obtained by the destructive distillation of wood, redistilled and treated with CaO, HO, yields about 1 p. c. of this substance, which is also called *pyroxylic spirit* and *wood naphtha*. It boils at 152°, has a density of 0.798, will burn feebly, is miscible with water, alcohol, and ether, and will dissolve most resins, as also negative gun-cotton, to form collodion.

(a) **Methylic Ether.**—C_2H_3O. Prepared by heating the above with 4 parts of strong Sulphuric Acid. It is a gas. Density 1.617, (liquefied only by great pressure,) of which water will dissolve 33 vols.

(*b*) When wood-spirit is exposed to the action of moistened platinum black, under a bell-jar, to which there is free access of air, oxygen is absorbed, and *formic acid* (so called from its occurrence in the bodies of red ants, formica rufa) is formed; thus, $C_2H_4O_2 + 4O = C_2H_2O_4 + 2HO$.

Formic Acid — $C_2H_2O_4$, is a clear liquid of acid taste, pungent odor, density 1.24, and when dropped upon the skin quickly blisters it. It boils at 212°, producing an inflammable vapor, and freezes at 32°. The alkaline formates are used in the reduction of metallic oxides.

3. It will be seen on inspection, that methylic-alcohol, $C_2H_4O_2$, and wine-alcohol, $C_4H_6O_2$; wood-ether, C_2H_3O, and sulphuric ether, C_4H_5O; formic acid, $C_2H_2O_4$, and acetic acid, $C_4H_4O_4$, all differ from one another by C_2H_2. Now, bodies which vary by C_2H_2, or by a multiple of it, are termed *homologous*, and their number is very great. If we add C_2H_2 to the alcohols, ethers and acids previously mentioned, we shall get long series of new alcohols and acids, many of whose members are already known to us; thus,

ALCOHOLS.		ACIDS.		ETHERS.	
Methylic,	$C_2H_4O_2$.	Formic,	$C_2H_2O_4$.	Methylic,	C_2H_3O.
Vinic,	$C_4H_6O_2$.	Acetic,	$C_4H_4O_4$.	Common,	C_4H_5O.
Propylic,	$C_6H_8O_2$.	Propionic,	$C_6H_6O_4$.		C_6H_7O,
Butylic,	$C_8H_{10}O_2$.	Butyric,	$C_8H_8O_4$.	Butylic,	C_8H_9O.
Amylic,	$C_{10}H_{12}O_2$.	Valeric,	$C_{10}H_{10}O_4$.	Amylic,	$C_{10}H_{11}O$.
	$C_{12}H_{14}O_2$.	Caproic,	$C_{12}H_{12}O_4$.		
	$C_{14}H_{16}O_2$.	Œnanthylic,	$C_{14}H_{14}O_4$.		
Caprylic,	$C_{16}H_{18}O_2$.	Caprylic,	$C_{16}H_{16}O_4$.	Caprylic,	$C_{16}H_{17}O$.

Besides the wine-alcohol obtained in the fermentation of saccharine matters, various acrid volatile-oils, called *fusel*-oils, are formed, which likewise yield on distillation alcoholic liquids. The fusel-oil obtained by fermenting the husk or *marc* of the grape, for example, yields *butyl*-alcohol, $C_6H_8O_2$, the fusel-oil of beet-root sugar produces

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propyl-alcohol, $C_8H_{10}O_2$, and that of potato-brandy, *amyl*-alcohol, $C_{10}H_{12}O_2$.

As methyl-alcohol, and wine-alcohol, yield formic acid and acetic acid by oxidation, so also propyl, butyl, and amyl-alcohol, are converted by absorption of oxygen into propionic, butyric, and valeric acids; thus, $C_4H_6O_2$ (wine-alcohol)$+4O=2HO+C_4H_4O_4$ (acetic acid), and $C_{10}H_{12}O_2$ (amyl-alcohol)$+4O=2HO+C_{10}H_{10}O_4$ (valeric acid).

By treatment with strong acids, the alcohols may be converted into ethers, as described on page 237.

As we pass from the lower members of these homologous series, to those containing a larger number of equivalents, we observe a corresponding change of properties; they constantly approach nearer the solid form, and their boiling points increase by a fixed quantity, in the series of acids about 35.88°.

II. Ethyl, Methyl, etc.—Compound radicals, resembling in their chemical relations, hydrogen and the metals.

Besides common Ether, C_4H_5O, a great many other bodies may be formed from alcohol, which possess the properties of ether, and are termed compound ethers, such as *Hydrochloric* Ether, C_4H_5Cl; Hydrobromic Ether, C_4H_5Br; Nitric Ether, C_4H_5O,NO_5; Oxalic Ether, C_4H_5O, C_2O_3, etc. Now all these compounds agree in containing C_4H_5; and it appears as though C_4H_5 might be transferred from one compound to another without suffering decomposition, in the same manner as an elementary body like zinc or copper. To a body which, like C_4H_5, plays the part of an element, we give a distinct name, and speak of it as a simple body. C_4H_5, for example, is denominated Ethyl, and represented by the symbol Ae.

Ethyl, like zinc, combines with the halogen bodies to form haloid salts, and with oxygen and sulphur to form oxides and sulphides. The oxides, in turn, combine with the different acids to form ordinary salts; thus:—

Ethyl (symbol Ae)............................... .... C_4H_5
Oxide of Ethyl, Ether .... C_4H_5O
Hydrate of Oxide of Ethyl, Alcohol... ... . C_4H_5O,HO
Chloride of Ethyl, Hydrochloric Ether .... C_4H_5Cl
Bromide of Ethyl, Hydrobromic Ether............. C_4H_5Br
Iodide of Ethyl, Hydriodic Ether.................... C_4H_5I
Cyanide of Ethyl...... ... ... C_4H_5Cy
Nitrate of Oxide of Ethyl, Nitric Ether............ C_4H_5O,NO_5
Silicate of Oxide of Ethyl, Silicic Ether.......... $3(C_4H_5O),SiO_3$

The theory stated above was proposed by Liebig, long before the compound radical C_4H_5 was ever known in the separate state. Afterwards it was isolated, as a colorless liquid, by Dr. Frankland, from Iodide of Ethyl, by exposing it to the action of finely-divided zinc, at a temperature of 330°. By reference to the above table of Ethyl compounds, it will be seen that ether, C_4H_5O, is an Oxide of Ethyl, and alcohol, C_4H_5O,HO, is a Hydrate of the Oxide of Ethyl, and that they may be expressed by the formulæ AeO and AeO,HO.

Ethyl may be made to enter into combination even with hydrogen and the metals, and a long series of related bodies may be formed, as —

Hydride of Ethyl.............................. $C_4H_5H=AeH$
Zinc-Ethyl...................................... $C_4H_5Zn=AeZn$
Stannethyl...................................... $C_4H_5Sn=AeSn$
Bismethyl....................................... $(C_4H_5)_3Bi=Ae_3Bi$
Plumbethyl..................................... $(C_4H_5)_3Pb_2=Ae_3Pb_2$
Stibethyl.. $(C_4H_5)_3Sb=Ae_3Sb$
Arsenethyl, etc................................ $(C_4H_5)_3As=Ae_3As$, etc.

And these compounds may be made to combine with the halogen bodies, or with oxygen and the acids, to form crystallizable salts, as, for example :—

Stannethyl .... $AeSn=C_4H_5Sn$
Oxide of Stannethyl................. $AeSnO=C_4H_5SnO$
Chloride of Stannethyl............. $AeSnCl=C_4H_5SnCl$
Nitrate of Stannethyl, etc.......... $AeSnO,NO_5=C_4H_5SnO,NO_5$. etc.

Methyl.—In like manner, in all the Methyl-Ethers it will be seen that C_2H_3 enters, and is displaced from combination, as a whole. This compound radical (C_2H_3) has not yet been isolated, but it has been confidently assumed to exist. It is known as *Methyl*, and represented by the symbol Me. Wood-ether is regarded as an Oxide, and wood-spirit as a Hydrated Oxide of Methyl; thus:—

Methyl.. $C_2H_3=Me$
Oxide of Methyl, Wood-Ether.................. $C_2H_3O=MeO$
Hydrate of Oxide of Methyl, Wood-Spirit.... $C_2H_3O,HO=MeO,HO$
Sulphate of Oxide of Methyl, etc.............. C_2H_3O,SO_3, etc.
Chloride of Methyl................................ C_2H_3Cl
Iodide of Methyl, etc............................. C_2H_3I, etc.
Hydride of Methyl................................. C_2H_3H
Zinc-Methyl, etc.................................... C_2H_3Zn, etc.
Kakodyl.. $C_4H_6As=(C_2H_3)_2As$

Kakodyl deserves especial mention. It is a compound radical, capable of entering into a large number of combinations, and of being displaced from them in the same manner as a metal. Its most important compounds are—

Kakodyl (symbol Kd)............................. C_4H_6As
Oxide of Kakodyl.................................. KdO
Chloride of Kakodyl............................... KdCl
Terchloride of Kakodyl........................... $KdCl_3$
Kakodylic Acid..................................... KdO_3
Kakodylate of Silver.............................. AgO,KdO_3
Tersulphide of Kakodyl........................... KdS_3

Oxide of Kakodyl — KdO. Cadet's Fuming Liquid, Alkarsin.

Preparation.—When equal weights of Acetate of Potassa and Arsenious acid are heated together, the acetone liberated by the decomposition of the Acetate of Potassa reacts upon the Arsenious acid to form Oxide of Kakodyl and Carbonic acid, $2(KO,C_4H_3O_3)=2KO+2CO_2+2C_2H_3O$,

and $2C_3H_3O + AsO_3 = C_4H_6AsO + 2CO_2$. This process may be conducted in an earthen retort placed in a furnace, and having its beak connected with a U shaped tube (Fig. 160) plunged in a vessel filled with broken ice. In this U tube the Oxide of Kako-dyl will collect with some water which covers it.

Fig. 160.

Properties. — A colorless, highly refrac-tive liquid; density 1.462, and boiling point 302°. It is highly poisonous, and attacks the eyes and lining membrane of the nose. It takes fire in air, producing water, car-bonic and arsenious acids. When treated with corrosive sublimate and hydrochloric acid it yields an extremely poisonous liquid, Chloride of Kakodyl.

Kakodyl—Kd.

Preparation.—Digested with zinc the Chloride of Kak-odyl suffers decomposition, with the formation of Chloride of Zinc and Kakodyl itself, $KdCl + Zn = ZnCl + Kd$.

Properties. — A colorless, transparent liquid, of great inflammability. It boils at 338°, and at 21° crystallizes in transparent square prisms. Combines directly with oxygen, sulphur, chlorine, etc. Its teroxide, *alkargen*, KdO_3, is a very stable acid, capable of uniting with me-tallic oxides to form crystallizable salts. It is not poison-ous. In union with cyanogen, as $KdCy$, it is said to form the most violent of all poisons.

Propyl, C_6H_7; Butyl, C_8H_9; Amyl, $C_{10}H_{11}$; etc.

These are the compound radicals of the series of alco-hols and ethers homologous with wood-spirit and wood-ether. As oxides they form ethers, and as hydrated oxides alcohols. (See page 243.) Their alcohols, when oxidized, yield homologous acids.

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Benzoyl, $C_{14}H_5O_2$; Cinnamyl, $C_{18}H_7O_2$; and Salicyl, $C_{14}H_5O_4$.

1. Benzoyl—$C_{14}H_5O_2$. Symbol, Bz.

Benzoyl is a compound radical, capable of isolation, which can be made to combine directly with chlorine, hydrogen, oxygen, etc., and to fulfil the part of a metal. Its most important compounds are—

Hydride of Benzoyl, Bitter-Almond Oil...........	$C_{14}H_5O_2H$
Hydrated Oxide of Benzoyl, Benzoic Acid........	$C_{14}H_5O_2HO,HO$
Chloride of Benzoyl....................................	$C_{14}H_5O_2Cl$
Benzoic Alcohol......................................	$C_{14}H_7O,HO$

Hydride of Benzoyl — BzH. *Bitter-Almond Oil.* This oil is obtained by distilling bitter almonds, after they have been crushed and the fixed oil expressed, with water. The water is essential to the formation of the oil, inasmuch as it acts upon a crystallizable principle, called *Amygdalin*, which exists in the seed, and, aided by nitrogenous substances, likewise contained in the pulp, forms from it bitter-almond oil.

Properties. — It is a thin liquid, of agreeable odor and high refractive power; its density is 1.043, and boiling point 356°. Exposed to the air, it absorbs oxygen with rapidity, and is converted into Benzoic acid.

Benzoic Acid—BzO,HO. It may be obtained in large quantities by heating some of the balsams, especially *gum benzoin.*

Properties.—It enters readily into combination with the alkalies and metallic oxides to form soluble crystallizable salts. By prolonged heating with fuming nitric acid it forms two new acids, *Nitrobenzoic,* $C_{14}(H_4NO_4)O_3,HO$ and *Binitrobenzoic,* $C_{14}(H_3(NO_4)_2)O_3,HO$; in the former of which one atom, and in the latter two atoms of hydrogen are replaced by Hyponitric acid. These substitutions are

of constant occurrence, and should be studied in order to understand important operations in manufacturing chemistry.

Benzol—$C_{12}H_6$.

Preparation.—It may be formed by decomposing Benzoic acid by Hydrate of Lime; thus, $C_{14}H_6O_4 + 2(CaO,HO)$ $= C_{12}H_6 + 2(CaO,CO_2) + HO$, or by distilling bituminous coal (see p. 233). Benzol has recently become of great importance, as the source of *Aniline*, by the following series of transformations: Benzol is first converted into *Nitrobenzol*, $C_{12}H_5NO_4$, by heating with fuming nitric acid, and then the nitrobenzol changed to aniline by distillation with acetic acid and iron filings, $C_1H_5NO_4 +$ $12(FeO,C_4H_3O_3) + 2HO = C_{12}H_7N + 6Fe_2O_3,12(C_4H_3O_3)$.

Aniline, $C_{12}H_7$, is an oily, colorless liquid, of density 1.028, and boiling point 360°. It enters into combination with acids and forms many beautiful crystallizable salts. That formed with sulphuric acid, the Sulphate of Aniline, gives with Bichromate of Potash the exquisite mauve color patented by Mr. Perkins, which was the first formed of the many commercial aniline dyes.

Cinnamyl — $C_{18}H_7O_2$, Symbol Ci.

Like benzoyl, this radical, when combined with hydrogen, yields an oil, the *Oil of Cinnamon*, $C_{18}H_7O_2$ H. Its hydrated oxide forms an analogous acid, *Cinnamic acid*, $C_{18}H_7O_2O,HO$. It unites with chlorine to form a *Chloride of Cinnamyl*, $C_{18}H_7O_2Cl$, and forms *Cinnamylic Alcohol*, $C_{18}H_9O,HO$, corresponding to Benzoic Alcohol, $C_{14}H_7O,$ HO.

Salicyl—$C_{14}H_3O_4$.

As a Hydride, $C_{14}H_5O_4$ H, Salicyl forms an oil, which has been found to be identical with that distilled from the flowers of meadow-sweet. This artificial oil has been obtained from *Salicin*, $C_{26}H_{18}O_4$, the bitter principle of poplar and willow bark.

III. VEGETABLE ACIDS.

Under this section are included those acids which are not formed artificially by oxidation of the alcohols or by other means, but exist ready formed in plants. They are sometimes met with in the free state, but generally in combination with bases. The most important are—

Oxalic Acid..........	$C_4O_6,2HO$	Malic Acid.........	$C_8H_4O_8,2HO$
Tartaric Acid.......	$C_8H_4O_{10},2HO$	Tannic Acid........	$C_{54}H_{19}O_{31},3HO$
Citric Acid..........	$C_{12}H_5O_{11},3HO$	Gallic Acid.........	$C_7HO_5,2HO$

Oxalic Acid—$C_4O_6,2HO$.

It is found in combination with potassa or lime in many plants, and particularly in various kinds of sorrel (*Oxalis*).

Preparation.—It may be formed by digesting any saccharine or amylaceous matter with moderately strong Nitric acid. Thus, 1 part of Sugar, 5 parts of Nitric acid of sp. gr. 1.42, and 10 parts of Water, when heated together, yield on cooling colorless crystals of Oxalic acid. The nitric acid gives up its oxygen to the sugar, and we have $C_{24}H_{18}O_{18}+36O=6(C_4O_6)+18HO$.

Properties. — Extremely sour, very soluble in water, highly poisonous, and capable of combining with the alkalies, earths, and metals to form crystalline salts. It is bibasic, and forms two series of salts, one containing 2 equivalents of the basic body, the other 1 equivalent along with one atom of water. Will remove stains made by common ink. Sold for this purpose under the name of Salts of Lemon.

Tartaric Acid—$C_8H_4O_{10},2HO$.

Found combined with potassa in many fruits, especially grapes, tamarinds, and pineapples.

Preparation.—When the juices of these fruits are fermented, as in the manufacture of wine, the Acid Tartrate of Potassa is thrown down, and forms a coating on the

sides and bottoms of the cask, called *Argol* or *Tartar*. When argol is repeatedly washed, filtered with animal charcoal, and crystallized, it is converted into *Cream of Tartar*, or nearly pure acid Tartrate of Potassa, $KO,HO,C_5H_4O_{10}$. From this substance, by neutralization with lime and subsequent removal of the bases by sulphuric acid, Tartaric acid may be obtained.

Properties.—Large, white, colorless, transparent crystals, readily soluble in water. Strongly acid to the taste, and quickly reddens litmus. It is bibasic, and, like all the other vegetable acids, containing 2 equivalents of basic water, forms two series of salts, one containing 2 and the other 1 equivalent of the base.

Use.—Tartaric acid is largely employed in calico printing, to liberate from bleaching powder the chlorine necessary to bleach part of the colored print, in order to form a pattern.

Its most important salts are—

Rochelle Salt—$KO,NaO,C_8H_4O_{10}+8HO$. *Tartrate of Potassa and Soda.* It is obtained, by neutralizing Cream of Tartar with Carbonate of Soda, in very soluble crystals. It is used as a purgative.

Tartar-Emetic—$KO,SbO_3,C_8H_4O_{10}+4HO$. Tartrate of Potassa and Antimony.

Preparation.—Equal parts of Cream of Tartar and Oxide of Antimony are boiled with 6 parts of water.

Use.—Largely employed in medicine.

Effervescing mixtures are composed either of Tartaric acid and Bicarbonate of Soda (*Soda powders*), or Tartaric acid and Bicarbonate of Soda with Rochelle Salt (*Seidlitz powders*).

Citric Acid—$C_{12}H_5O_{11},3HO$.

Exists in the juices of the lemon (*citron*) and, to a smaller extent, of orange, currant, gooseberry, etc.

Preparation.—A Citrate of Lime is formed, in the first

place, by neutralizing lemon-juice with lime, and afterwards decomposed by sulphuric acid.

Properties. — On evaporation, the citric acid thus set free, separates in colorless crystals of great solubility, strongly acid character, and agreeable taste. It is, as its formula indicates, tribasic. By heating with Nitric acid, it is converted into Oxalic acid; with Caustic potassa, into Oxalic and Acetic acids.

Uses. — In calico printing; in imparting an agreeable flavor to cookery; in making effervescent drinks, and as a *Citrate of Magnesia*, for a pleasant-tasting cathartic.

Tests. — A white precipitate with *baryta, strontia,* and *lead.*

Malic Acid—$C_8H_4O_8,2HO$.

Sources. — It is found in large quantities in unripe fruits, such as the apple (*Malum*), pear, plum, etc.; also in vegetables, such as the rhubarb, or pie-plant.

Properties. — Forms soluble crystals, which melt at 181°. By heating, it is converted into two other acids, the *maleic* and *paramaleic* or *fumaric* acids, both of which have the formula $C_8H_2O_6,2HO$, and are therefore isomeric, that is, they consist of the same elements in the same proportion.

Tannic Acid—$C_{54}H_{19}O_{31},3HO$.   Tannin.

Sources.—Found in the bark and leaves of the oak, chestnut, hemlock, and many other trees. Forms a large portion of *nutgalls*, which are excrescences upon oak leaves.

Preparation. — It may be obtained by steeping powdered nutgalls in Sulphuric ether.

Properties.—It hardens as a yellow substance, devoid of crystalline structure, which is soluble in water, and of peculiar, astringent taste; it reddens litmus, and forms salts with bases; but its acid characters are feeble.

Uses. —With Sesquioxide of iron, it forms a Tannate,

which, when mixed with gum to hold the insoluble Tannate of iron in suspension, constitutes *common writing ink*. Besides its employment in ink making, it is used in enormous quantities in *tanning*. After the hair has been removed from hides, they are soaked in vats containing oak and hemlock bark. The Tannic acid so obtained unites with the Gelatine contained in the hides, and forms an insoluble compound with it, which is the basis of *leather*.

Gallic Acid—$C_7HO_3,2HO$.

Preparation.—It is found, along with Tannic acid, in vegetable bodies, and produced whenever this acid is exposed to the atmosphere, or boiled with Sulphuric acid.

Properties.—A crystalline body, insoluble in cold, but very soluble in hot water. It is converted by heating into *Pyrogallic* and *Metagallic acids*: thus, $C_7H_3O_5 = CO_2 + C_6H_3O_3$ (*Pyrogallic acid*), and $C_6H_3O_3 = HO + C_6H_2O_2$ (*Metagallic acid*).

Uses.—A Tanno-gallate of Iron mixed with Sulphate of Indigo forms *blue ink*. Gallic and Pyrogallic acids are also employed to develop photographs.

IV. ORGANIC BASES.

I. ORGANIC ALKALIES, OR ALKALOIDS.

Some are found ready formed, others are obtained from plants by destructive distillation. They are always found in combination with peculiar acids, forming true salts. All contain nitrogen. In water, they dissolve sparingly, readily in alcohol, and on cooling, form beautiful crystals A few however, are oily, volatile liquids. They have a very bitter taste, and are highly poisonous: the proper antidotes are animal charcoal and tannin. The most important are:—

Morphia .... $C_{34}H_{19}NO_6+2HO$
Narcotina .... $C_{46}H_{25}NO_{14}.$
Cinchonia .... $C_{40}H_{24}N_2O_2.$
Quinia........................... $C_{40}H_{24}N_2O_4.$
Strychnia........................ $C_{42}H_{23}N_2O_4.$
Brucia........................... $C_{46}H_{26}N_2O_6.$
Veratria .... $C_{64}H_{52}N_2O_{16}.$
Caffeine .... $C_{16}H_{16}N_4O_4.$
Conia............................ $C_{16}H_{17}NO_2.$
Nicotina .... $C_{10}H_7N.$

Morphia—$C_{34}H_{19}NO_6+2HO$ (crystallized).

Sources.—Exists along with *narcotina, codeia, thebaia, papaverina, opianine, resin, oil, gum,* etc., in *opium,* or dried poppy-juice. They are found in combination with a peculiar acid, the *meconic* (from *mecone,* a poppy). In 100 parts of opium, there are 7 per cent. of Meconic acid, 10 of Morphia, and 7 of Narcotina.

Preparation.—It is separated by digesting opium for several days in alcohol, and precipitating by ammonia. The morphia thus obtained, is purified by solution in boiling alcohol, from which it deposits on cooling.

Properties. —It crystallizes in brilliant rectangular prisms, which contain 2 equivalents of water of crystallization. At a gentle heat the water is driven off, and the morphia solidifies into a resinous mass. It requires 1000 parts of cold, or 400 of hot water for solution; of alcohol, only 30 parts; dissolves also in acids, fixed alkalies, and alkaline earths.

Use.—In doses of $\frac{1}{8}$ to $\frac{1}{4}$ of a grain employed in medicine; so likewise the Sulphate, Muriate, and Acetate of Morphia.

Tests. — Colored *green* by mixture of Nitric and Sulphuric acids; *blue* by neutral solution of Perchloride of Iron.

Cinchonia, $C_{40}H_{24}N_2O_2$, and Quinia, $C_{40}H_{24}N_2O_4$.

Source.—They are found associated together in the bark

of the *Cinchona* tree, which grows extensively in South America, and is known in commerce as Peruvian bark. The former is found most abundantly in the pale or *Loxa bark;* the latter in the yellow or red, the *Calisaya bark.* They are combined with *Kinic acid.*

Preparation. — The powdered bark is dissolved in alcohol, the alkaloid precipitated by lime or ammonia, then boiled in alcohol and converted into Sulphate. From solution, the Sulphate of Quinia, being less soluble, crystallizes out first.

Properties. — Cinchonia crystallizes in very beautiful transparent prisms. It has strongly basic properties, and forms many crystallizable salts. It turns the plane of polarized rays to the right.

Quinia crystallizes less distinctly, but is more soluble than Cinchonia. It has an intensely bitter taste; rotates the plane of polarization to the left. Its most important salts are the *Muriate* and

Sulphate of Quinia, $C_{40}H_{24}N_2O_4,HO,SO_3+7HO.$ This is the neutral Sulphate, but there is likewise an acid salt. It forms with iodine a beautiful crystalline body, which has the same absorbent power upon light as *tourmaline,* and may be used as a substitute for it in the polariscope.

Uses.—Quinia is very largely employed in medicine on account of its febrifuge and antiperiodic powers; Sulphate of Quinia to display the phenomena of fluorescence.

Isomeric Bodies.—If these Quinia salts be exposed to sun-light, or treated with excess of acid, they pass into a resinous condition, and constitute *Quinoidine.* This is in reality a mixture of two alkaloids, one of which has the same properties and is isomeric with Quinia, *Quinidine,* the other isomeric with Cinchona, *Cinchonidine;* and when these two substances are exposed to a temperature of 250° they are changed into two other isomeric bodies, *Quinicine* and *Cinchonicine.* The most remarkable dif-

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ference between them all is in their action upon the plane
of polarization; for

Quinia produces a powerful rotation to the left.
Quinidine "   "   "   "   right.
Quinicine "   feeble   "   "   right.
Cinchona   "   powerful   "   "   right.
Cinchonidine "   "   "   "   left.
Cinchonicine "   feeble   "   "   right.

Strychnia, $C_{44}H_{23}N_2O_4$, and **Brucia,** $C_{46}H_{26}N_2O_8$.

Source.—They are found associated together in the fruit
and bark of *Nux Vomica* and in *St. Ignatius Bean.* In
the former they are combined with lactic acid.

Preparation. — They are precipitated by excess of hy-
drate of lime, filtered from solution in boiling alcohol, and
afterwards separated by cold alcohol. Strychnia crystal-
lizes out first.

Properties.—Small, transparent, colorless, very brilliant
octahedrons; soluble in 6667 parts cold and 2000 parts
boiling water; very slightly soluble in cold alcohol or ether.
Very bitter and fearfully poisonous.

Brucia is distinguished from Strychnia by its ready sol-
ubility in alcohol, and by giving, when its salts are mixed
with Tartaric acid, no precipitate with Bicarbonate of
Soda.

Tests.—Moistened with Sulphuric acid, Strychnia gives
with Bichromate of Potassa a beautiful violet tint, passing
into pale rose. Brucia and its salts afford a bright scarlet
color, gradually passing into yellow with Nitric acid; on
addition of Protochloride of Tin a fine violet.

Veratria—$C_{64}H_{52}N_2O_{16}$.

Source.—Occurs principally in combination with Gallic
acid in several varieties of *Veratrum.*

Properties. — An acrid, fearful poison, producing, on
contact with the nasal membrane, dangerous fits of
sneezing.

Use.— Sedative in neuralgia, when applied as an external ointment.

Test.—Strikes with Nitric acid a red color slowly changing to yellow.

Caffeine, $C_{16}H_{10}N_4O_4$, or **Theine.**

Remarkable as being found in coffee-grains and tea-leaves, in the leaves of *Paullinia sorbilis*, and in those of *Ilex Paraguayensis*, from which the universal beverages are obtained.

Conia, $C_{16}H_{15}N$, and **Nicotina,** $C_{10}H_7N$.

They differ from all other alkaloids in forming oily, volatile liquids. The first is the poisonous principle of hemlock, the second of tobacco.

II. ARTIFICIAL ORGANIC BASES, OR ARTIFICIAL ALKALOIDS.

The best method of studying the production and constitution of these bodies is by comparing them with ammonia; for, like ammonia, they all contain nitrogen, have alkaline properties, and are capable of combining with acids to form crystallizable salts. They may be considered, indeed, as ammonia, in which one or more equivalents of hydrogen are replaced by the same number of equivalents of the compound radicals, *ethyl, methyl, phenyl,* etc.; thus

$$N\begin{cases}H\\H\\H\end{cases} \qquad N\begin{cases}C_4H_5\\H\\H\end{cases} \qquad N\begin{cases}C_4H_5\\C_4H_5\\H\end{cases} \qquad N\begin{cases}C_4H_5\\C_4H_5\\C_4H_5\end{cases}$$

Ammonia. Ethyl-ammonia, Biethyl-ammonia, Triethyl-ammonia,
or Ethylamine. or Biethylamine. or Triethylamine.

The Ethyl Ammonias.

1. **Ethylamine**—$N(C_4H_5)H_2 = C_4H_7N$.

Preparation. — Formed by heating strong ammonia with iodide of ethyl in hermetically sealed tubes: thus, $C_4H_5I + NH_3 = N(C_4H_5)H_3I$, and distilling the product

with caustic potash, $N(C_4H_5)H_3I + KO = N(C_4H_5)H_3 +$ $HO + KI$.

Properties.—A thin mobile fluid, strongly alkaline, and combining, like Ammonia, to form many crystallizable salts. It forms a Hydrochlorate of ethylamine, with the formation of white clouds, similar to those arising from the combination of Hydrochloric acid and Ammonia. Like Ammonia, it precipitates the Salts of Alumina, Magnesia, Iron, Manganese, Bismuth, Chromium, Tin, Lead, and Mercury.

Biethylamine—$N(C_4H_5)_2H = C_8H_{11}N$, and

Triethylamine—$N(C_4H_5)_3 = C_{12}H_{15}N$.

Preparation.—They are produced by reactions analogous to those between ammonia and bromide of ethyl; ethylamine, or biethylamine taking the place of the former: thus, $N(C_4H_5)H_2 + C_4H_5Br = N(C_4H_5)_2H_2Br$; and $N(C_4H_5)_2H_2Br + KO = N(C_4H_5)_2H + HO + KBr$.

Properties.—With the increase of equivalents of the elements composing them, there is a corresponding rise of boiling point; ethylamine boiling 54.4°, biethylamine at 133°, triethylamine at 195.8°. Their alkaline properties correspondingly diminish, though all form beautiful salts. As we have

$$N \begin{Bmatrix} H \\ H \\ H \\ H \end{Bmatrix} O, HO \qquad \text{so} \qquad N \begin{Bmatrix} C_4H_5 \\ C_4H_5 \\ C_4H_5 \\ C_4H_5 \end{Bmatrix} O, HO.$$
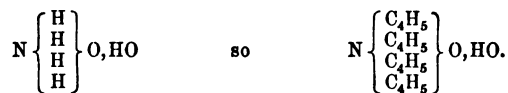
Hydrated oxide of ammonium. Hydrated oxide of tetrethyl-
             ammonium.

Hydrated Oxide of Tetrethyl-ammonium — $N(C_4H_5)_4 = C_{16}H_{20}N$.

Properties.—It is powerfully alkaline, and closely resembles potassa, or soda, combining like them with fatty acids to form true soaps, and with metallic salts acting precisely like potassa. In its excessively bitter taste, resembles the alkaloids proper.

The Methyl Ammonias.

$$N \left\{ \begin{array}{l} C_2H_3 \\ H \\ H \end{array} \right. \qquad N \left\{ \begin{array}{l} C_2H_3 \\ C_2H_3 \\ H \end{array} \right. \qquad N \left\{ \begin{array}{l} C_2H_3 \\ C_2H_3 \\ C_2H_3 \end{array} \right. \qquad N \left\{ \begin{array}{l} C_2H_3 \\ C_2H_3 \\ C_2H_3 \\ C_2H_3 \end{array} \right\} O,HO$$
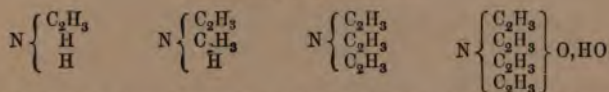
Methylamine.	Bimethylamine.	Trimethylamine.	Hydrated oxide of
$=C_2H_5N.$	$=C_4H_7N.$	$=C_6H_9N.$	tetremethyl-am-monium.

Preparation.—As hydrated cyanic acid (C_2NO,HO), when boiled with caustic potassa, is decomposed into 2 Eq. of Carbonic acid and 1 Eq. of Ammonia, so is Cyanate of Ethyl, or Methyl, into 2 Eq. of Carbonic acid and 1 Eq. of Ethylamine, or Methylamine: thus, $C_2NO,HO+2(KO,HO)=2(KO,CO_2)+NH_3$; and $C_2NO,(C_4H_5)O$ or $C_2NO,(C_2H_3)O + 2(KO,HO) =2(KO,CO_2) + N(C_4H_5)H_2$; or $N(C_2H_3)H_2$.

Properties.—The first three are gases closely resembling ammonia. Methylamine smells slightly fishy, Trimethylamine strongly so; the latter is found in considerable quantity in the roe of herring. The density of Ammonia is 0.589, of Methylamine 1.08; the former is soluble in $\frac{1}{700}$ its bulk of water, the latter in $\frac{1}{1000}$, and, consequently, is the most soluble of all gases.

The Amyl Ammonias.

$$N \left\{ \begin{array}{l} C_{10}H_{11} \\ H \\ H \end{array} \right. \qquad N \left\{ \begin{array}{l} C_{10}H_{11} \\ C_{10}H_{11} \\ H \end{array} \right. \qquad N \left\{ \begin{array}{l} C_{10}H_{11} \\ C_{10}H_{11} \\ C_{10}H_{11} \end{array} \right. \qquad N \left\{ \begin{array}{l} C_{10}H_{11} \\ C_{10}H_{11} \\ C_{10}H_{11} \\ C_{10}H_{11} \end{array} \right\} O,HO.$$
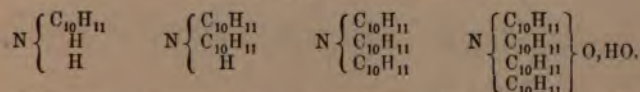
Amylamine.	Biamylamine.	Triamylamine.	Hydrated oxide of Te-
$=C_{10}H_{13}N.$	$=C_{20}H_{23}N$	$=C_{30}H_{33}N.$	tramyl-ammonium.

Properties.—A series of strongly alkaline bodies, whose basic power diminishes and boiling point increases as the series ascends; thus, Amylamine boils at 199.4°, Biamylamine at 338°, Triamylamine at 494.6°.

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Phenyl Ammonia.

Aniline or **Phenylamine**—$N(C_{12}H_5)H_2 = C_{12}H_7N$.

Preparation. — When Salicylic acid, $C_{14}H_4O_42HO$ (p. 247), is strongly heated it is decomposed into Carbonic acid and Carbolic acid or *Phenol*, $C_{12}H_6O_2$. The same body is found in the acid portion of coal-tar (p. 233). It so closely resembles the alcohols that it is assumed to be in composition a hydrated oxide of a compound radical, *Phenyl*, $C_{12}H_5$ (Sym. Pyl); and the body formed by heating Phenol with Ammonia, Aniline, $C_{12}H_7N$ (p. 259), has in like manner been regarded as a phenyl-ammonia; thus, $PylO,HO + NH_3 = 2HO + N(Pyl)H_2$, or $C_{12}H_7N$.

Substitution-Products of Aniline. — Besides the substitution of compound radicals for the hydrogen in Ammonia, the hydrogen of the new artificial bases may in like manner be replaced by *Chlorine, Bromine, Hyponitric acid,* etc.; thus—

Ammonia..	NH_3
Aniline...	$N(C_{12}H_5)H_2$
Chloraniline	$N(C_{12}H_4Cl)H_2$
Bromaniline....................................	$N(C_{12}H_4Br)H_2$
Bibromaniline.................................	$N(C_{12}H_3Br_2)H_2$
Nitraniline......................................	$N(C_{12}H_4NO_4)H_2$

.III. ARTIFICIAL ALKALOIDS HOMOLOGOUS WITH ANILINE.

As we had a hydrocarbon Benzol, $C_{12}H_6$ (p. 246), derived from the radical Benzoyl, $C_{14}H_5O_2$, so likewise from the homologous radicals, *Toluyl*, $C_{16}H_7O_2$; *Xylil*, $C_{18}H_9O_2$; *Cumyl*, $C_{20}H_{11}O_2$, and *Cymyl*, $C_{22}H_{13}O_2$, result the hydrocarbons homologous with Benzol, $C_{12}H_6$, namely, *Toluol*, $C_{14}H_8$; *Xylol*, $C_{16}H_{10}$; *Cumol*, $C_{18}H_{12}$, and *Cymol*, $C_{20}H_{14}$.

And as Benzol was converted into Nitrobenzol by fum-

ing Nitric acid, so may its homologues be changed to homologous nitro-substitution hydrocarbons; and the action of Sulphuretted Hydrogen upon these last is the same as its action on Nitrobenzol, $C_{12}H_5NO_4$, viz., $C_{12}H_5NO_4 + 6HS = C_{12}H_7N + 4HO + 6S$. We have formed in this manner:—

Benzol,	$C_{12}H_5H$	Nitrobenzol,	$C_{12}H_5NO_4$	Aniline,	$N(C_{12}H_5)H_2$
Toluol,	$C_{14}H_7H$	Nitrotoluol,	$C_{14}H_7NO_4$	Toluidine,	$N(C_{14}H_7)H_2$
Xylol,	$C_{16}H_9H$	Nitroxylol,	$C_{16}H_9NO_4$	Xylidine,	$N(C_{16}H_9)H_2$
Cumol,	$C_{18}H_{11}H$	Nitrocumol,	$C_{18}H_{11}NO_4$	Cumidine,	$N(C_{18}H_{11})H_2$
Cymol,	$C_{20}H_{13}H$	Nitrocymol,	$C_{20}H_{13}NO_4$	Cymidine,	$N(C_{20}H_{13})H_2$

Properties.—They resemble, in their derivation, formation, and properties, Aniline. They form beautifully crystalline salts.

IV. ARTIFICIAL ALKALOIDS CONTAINING SEVERAL COMPOUND RADICALS.

The Hydrogen in Ammonia may not only be replaced by a single compound radical, but also by several different ones. In this manner Ethyl, Methyl, etc, may occur in the same artificial base:—

Ammonia......................	NH_3	Ethylaniline..............	$NPylAeH$
Aniline........................	$NPylH_2$	Biethylaniline	$NPylAe_2$

So from

Hydrated Oxide of Ammonium......................			NH_4O,HO
"	"	Triethyl-phenyl-ammonium	$N(PylAe_3)O,HO$
"	"	Triethyl-amyl-ammonium...	$N(AylAe_3)O,HO$
"	"	Methyl-biethyl-amyl-ammonium............................	$N(AylAc_2Me)O,HO$
"	"	Methyl-ethyl-amyl-phenyl-ammonium	$N(PylAylAeMe)O,HO$

Properties.—All these Ammonium bases are powerfully alkaline, and resemble strikingly the Hydrated Oxide of Tetretoyl-ammonium, p. 256.

V. OILS.

The term Oil is applied to a great variety of bodies, which agree in the general properties of inflammability, sparing solubility in water, and ready solubility in alcohol or ether. It is usual to associate *greasiness* with oils, but this idea requires limitation. Fixed oils (see below) are greasy, volatile oils are not; they are harsh to the touch. Mineral oils are intermediate. And when a cork is twisted into a bottle containing a fixed oil it makes no noise; in other oils it squeaks.

Classification of Oils. — They are most conveniently divided into three classes, according to their origin, viz., vegetable, animal, and mineral. The latter have been treated, under the changes produced in lignine by decay and distillation (p. 233); the former agree so closely in all their properties, that they are best considered together.

Classification of Vegetable and Animal Oils. — Vegetable and animal oils are of two kinds, (*a*) *fixed* and (*b*) *volatile;* so named from producing, the former a permanent, the latter a transient, stain when dropped on paper. Both classes absorb oxygen; some slowly, others so rapidly as to inflame spontaneously. In consequence of this difference, oils are farther divided into *drying* — those which, like linseed, poppy-seed, and walnut oils, become hard on exposure to air — and *non-drying* — those rancidifying only, as olive, palm, and most animal oils. In virtue of their siccative properties, drying oils are largely employed in painting.

Sources of Oils. — Oils are found in the stems, leaves, and fruits of plants, but abound chiefly in the seed. In animals they are stored up everywhere, but principally just beneath the cuticle; also in the omentum and around the kidneys.

Properties. — They are generally lighter than water, the

fixed oils varying in density from 0.91 to 0.94, and the volatile from 0.846 to 1.097. They vary likewise in their melting points, some being solid at ordinary temperatures, others liquid. In general, the greater the proportion of carbon they contain the higher the melting point.

(a) Fixed Oils, also called Fats.

Preparation.—When found in vegetables, they are obtained by submitting the crushed seeds or other vegetable structure to pressure, or pressure and heat combined. From animals they are obtained by breaking up the adipose membrane. This may be effected sometimes by the decay of the cellular structure, in other cases by liquefaction and expansion of the fat, which runs out or collects, on boiling, at the surface of the water.

Properties.—They are generally colorless, or of a slight yellow tinge, bleaching on exposure to light; of faint odor and slight taste. In some cases, however, peculiar odors are imparted by volatile fatty acids, as to butter by *butyric acid,* or by various ethers. They are all insoluble in water, and, with the exception of castor-oil, but slightly soluble in alcohol. In ether, the essential oils, and benzol they dissolve freely. They can be heated to nearly 500° without much change, but beyond that point they are decomposed, and cannot therefore be distilled. When heated to about 500°, they change color and evolve offensive odors; at a little above 600°, they are decomposed and distil, with the formation of solid and liquid hydrocarbons, water, fatty acids, and *Acrolein,* $C_6H_4O_2$— an excessively volatile, irritating liquid.

Composition.—They all consist of carbon, hydrogen, and oxygen; for example, in 100 parts of the following oils there are

	Carbon.	Hydrogen.	Oxygen.
Olive	77.21	13.36	9.43
Almond	77.40	11.48	10.82
Linseed	76.01	11.35	12.62
Castor	14.17	11.03	14.78
Whale	76.13	12.40	11.50
Spermaceti	78.91	10.97	10.12
Hog's Lard	79.09	11.14	9.75
Suet	78.99	11.70	9.30
Butter	65.60	17.60	16.80

The fixed oils are not composed, however, of a single substance, but are, for the most part, mixtures of at least three closely-related, proximate fatty principles, viz., *stearin* (from στέαρ, suet), *margarin* (from μάργαρον, a pearl), and *olein* (from ἔλαιον, oil). The two former are solid, the latter liquid at ordinary temperatures. As the amount of olein increases, so does the softness of the fat, while the boiling point correspondingly falls.

Saponification.—Fats and fixed oils generally are to be regarded as chemical salts formed by the union of certain organic acids, such as Stearic, Margaric, and Oleic, with a base called Glycerin. These salts are distinguished by the names Stearin, Margarin, and Olein respectively. They are all incapable of dissolving in, or even mixing with, water. If however these fats are heated with a solution of caustic alkali, the glycerin is displaced by the more powerful base, and new salts of the alkali are formed, which are soluble in water and are known as soaps. (See next page.) If to the above alkaline fat-salts a strong acid, such as Sulphuric, is added, the base is in turn taken from the acids, and the latter are then set free, and are found to be white crystallizable bodies soluble in warm water and showing an acid reaction.

Stearin, $C_{114}H_{110}O_{12} + 3HO =$ Glycerin, $C_6H_5O_3,3HO +$ 3 Stearic acid, $C_{36}H_{35}O_3,HO$;

Margarin, $C_{108}H_{104}O_{12}+3HO =$ Glycerin, $C_6H_5O_3,3HO+$ 3 Margaric acid, $C_{34}H_{33}O_3,HO$;

Olein, $C_{114}H_{104}O_{12} + 3HO =$ Glycerin, $C_6H_5O_3,3HO + 3$ Oleic acid, $C_{36}H_{33}O_3,HO$.

And, in case of palm-oil—

Palmitin, $C_{102}H_{98}O_{12}+3HO=$Glycerin, $C_6H_5O_3,3HO+3$ Palmitic acid, $C_{32}H_{31}O_3,HO$.

Process of Soap-Making. — The mixture of alkali and fat is heated together, by means of steam, in large iron vessels, called *coppers*. Salt water is then added to cut the viscid fluid so formed. The glycerin, being soluble in brine, is carried with it to the bottom of the copper; the soap, being insoluble in both brine and water, rises to the surface of the latter, and is then ladled out, pressed, and cut into cakes.

Process of Candle-Making. — The object to be attained in the manufacture of candles is to get the fatty acids in the free state and in a pure condition. This is effected in a variety of ways: —

1st. By making, in the first place, a soap out of fat, by means of lime, and afterwards decomposing this soap with Sulphuric acid. Sulphate of lime, being insoluble, sinks to the bottom, and the fatty acids rise to the surface of the heated liquid.

2nd. By heating fats with Sulphuric acid. At a high temperature the glycerin of the fat and Sulphuric acid are mutually decomposed, Sulphurous and Carbonic acids are evolved and the fatty acids set free.

3rd. By injecting steam at a temperature of 500° and 600° into heated fat, the latter is decomposed, and the glycerin and fatty acids, in a separate and very pure state, are distilled over, and may be obtained separately. This is the admirable process of Mr. Wilson.

Besides stearin, margarin, and olein, certain fats contain peculiar proximate fatty principles; thus,

Palm-oil yields *Palmitin*, $C_{102}H_{98}O_{12}$;

Butter yields *Butyrin*;

Beeswax yields *Cerin*, $C_{108}H_{108}O_4$, and *Myricin*, $C_{92}H_{92}O_4$;

Spermaceti yields *Cetin*, $C_{64}H_{64}O_4$.

By saponification of these fatty principles, we find that

Palmitin, $C_{102}H_{98}O_{12} =$ Glycerin, $C_6H_5O_5,3HO + 3$ Palmitic acid, $C_{32}H_{31}O_3,HO$;

Butyrin $=$ Glycerin, $C_6H_5O_0,3HO +$ (Butyric, Caproic, Caprylic, and Capric acids);

Cetin, $C_{64}H_{64}O_4 =$ Oxide of Cetyl, $C_{32}H_{35}O +$ Palmitic acid;

Cerin, $C_{108}H_{108}O_4 =$ Oxide of Cerotyl, $C_{54}H_{55}O +$ Cerotic acid;

Myricin, $C_{92}H_{92}O_4 =$ Oxide of Melissyl, $C_{92}H_{92}O_4 +$ Palmitic acid.

Spermaceti is therefore composed, in great measure, of Palmitate of Oxide of Cetyl, $C_{32}H_{35}O,C_{32}H_{31}O_3$; beeswax of Cerotate of Oxide of Cerotyl, $C_{54}H_{55}O,C_{54}H_{53}O_3$. These various compound radicals and acids are homologues of Methyl and Formic acid; thus—

Formic Acid....................................			C_2HO_3,HO
Butyric "	$(C_2H_2 \times 3)$	$+C_2HO_3,HO =$	$C_8H_7O_3,HO$
Caproic "	$(C_2H_2 \times 5) +$	" $=$	$C_{12}H_{11}O_3,HO$
Caprylic "	$(C_2H_2 \times 7) +$	" $=$	$C_{16}H_{15}O_3,HO$
Capric "	$(C_2H_2 \times 9) +$	" $=$	$C_{20}H_{19}O_3,HO$
Palmitic "	$(C_2H_2 \times 15) +$	" $=$	$C_{32}H_{31}O_3,HO$
Margaric "	$(C_2H_2 \times 16) +$	" $=$	$C_{34}H_{33}O_3,HO$
Stearic "	$(C_2H_2 \times 17) +$	" $=$	$C_{36}H_{35}O_3,HO$
Cerotic "	$(C_2H_2 \times 26) +$	" $=$	$C_{54}H_{53}O_3,HO$
Melissic "	$(C_2H_2 \times 29) +$	" $=$	$C_{60}H_{59}O_3,HO$

Glycerin, the *base* in all these fat-salts, is a sweet syrupy liquid, of sp. gr. 1.27, which does not evaporate, but dissolves freely in water. Mixed NO_5 and SO_3, convert it into nitro-glycerin, a body exploding with great violence by concussion, or at a temperature of 360°.

(b) Essential, or Volatile Oils.

The term essential is applied to volatile oils, because they confer distinguishing smell and properties to the plants composing them.

Preparation.— These Essential oils are found in the leaves, flowers, fruits, and seeds of plants. In some cases, as the orange-tree, the leaves, flowers, and fruit each yield a distinct oil. They are generally obtained by distilling the plant with water, the plant being in some cases fresh, in others salted or dried. When it is inclosed in cellular structure, as of orange or lemon-peel, it is procured by expression. Though the boiling-points of these oils is above the boiling-point of water, they are carried over with steam at 212°, and condensed with it in a refrigerator attached to the still.

Most of these oils are lighter than water, and float in a pure condition upon the surface of the water in the refrigerator; a portion, however, of the oil is always held in solution, constituting what is termed *perfumed* or *medicated waters*. To separate the oil from the perfumed water, they are poured into a *Florentine receiver*. It is conical in form, and at the side is a spout, *b c*, communicating with the bottom, the orifice *c* of the spout being much lower than the mouth *a* of the receiver. The distilled product being

Fig. 161.

poured into this vessel, the oil B separates from the water A, and occupies the upper part of the vessel. The water, as it rises above the bend of the spout, flows off at *c*, while the Essential oil may be from time to time removed by means of a pipette.
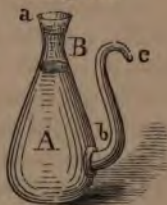
When the oil, as happens with that from jasmine, violet, tuberose, narcissus, etc., is too small in quantity and too

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delicate to be collected by expression or distillation, the
flowers are laid between woollen cloths saturated with an
inodorous fixed oil. The latter absorbs the essential oil
of the flowers, and afterwards, by digesting the cloths in
alcohol, an *essence* is obtained, free from fixed oil, which
is insoluble in alcohol.

Essential oils are mostly colorless when newly made
and pure, but by absorption of oxygen they become yellow
or brown, and even in some cases green and blue. Some
of them, however, are bleached on exposure to light.

They are generally of an agreeable odor, strongly aro-
matic and even burning flavor, and a few are poisonous.
They dissolve freely in ether and alcohol, and mix in all
proportions with fixed oils.

Classification of Essential Oils.—They are divided ac-
cording to their composition, into

(*a*) Hydrocarbon Oils, composed of Carbon and Hy-
drogen;

(*b*) Oxyhydrocarbon Oils, composed of Carbon, Hydro-
gen, and Oxygen;

(*c*) Essential Oils containing Sulphur.

Most of the essential oils, however, are mixtures of *a*
and *b*, and in many cases the latter, when isolated, is a
solid, resembling camphor. To the hydrocarbon Berze-
lius gave the name *stearoptene*, and to the oxyhydrocarbon,
elaioptene from στέαρ, fat, or ἔλαιον, oil, and κτηνὸς, volatile).
They may be separated by cold, which converts the cam-
phor into a solid, or by distillation, when the hydrocarbon
passes over first.

By exposure to air the Essential oils suffer two kinds of
changes: some absorb oxygen, and form with it crystal-
line and oftentimes acid compounds; others part with a
portion of their hydrogen, which forms with oxygen water,
and solidify into *resins*.

By the action of Chlorine, Iodine, and Bromine, Hy-

drochloric, Hydriodic, and Hydrobromic acids are formed, along with compounds of these gases and acids, with the remaining portion of the oil. In violent changes, sometimes thus produced, inflammation occurs.

(a) Hydrocarbon Essential Oils.

These present a remarkable sameness of composition, containing about 88 or 89 per cent. of carbon, and 11 or 12 per cent. of hydrogen, and may therefore be represented by the formula C_5H_4. Their different varieties may consequently be regarded as isomeric modifications of C_5H_4, or $C_{10}H_8$, or $C_{20}H_{16}$, or $C_{40}H_{32}$. All these formulæ represent equally well the composition of the oils by weight, one being sometimes preferred to the other merely on considerations relative to their different vapor densities. The most important are : —

Oil of Turpentine, *Camphene*, $C_{20}H_{16}$, and Oil of Lemon, $C_{10}H_8$.

Preparation.—The former is obtained by distilling turpentine with water, the latter by expressing the yellow portion of lemon-peel. Turpentine is a viscid fluid, consisting of oil of turpentine holding *rosin* in solution, which exudes at certain seasons of the year from incisions in the bark of pine trees. *Spirits of turpentine* is impure camphene containing some rosin; *burning fluid* is camphene mixed with three or four times its bulk of alcohol.

By the action of Hydrochloric acid Camphene and Oil of Lemons are each converted into two *artificial camphors*, much resembling common camphor in appearance and properties, one of them being solid and the other liquid at ordinary temperatures. The oils of *orange-peel, elemi, bergamot, pepper, juniper, cubebs, copaiba*, etc., are similar in composition to the above, and are all isomeric, but having a different specific gravity and boiling point.

(b) **Oxyhydrocarbon Essential Oils.**

These comprise most of the volatile oils used for medicine and perfumery. The three most important, oil of bitter almonds, cinnamon, and meadow-sweet, have already been described as hydrides of the compound radicals benzoyl, cinnamyl, and salicyl. Of the remainder,

Oil of Aniseed consists of a fluid oil and a crystalline solid, $C_{20}H_{12}O_2$;

Oil of Cumin consists of *Cymol*, $C_{20}H_{14}$ (liquid), and *Cuminol*, $C_{20}H_{12}O_2$ (liquid);

Oil of Thyme consists of several substances, chiefly *Thymol*, $C_{20}H_{14}O_2$ (solid);

Oil of Rue consists of several substances, chiefly the liquid $C_{20}H_{20}O_2$;

Oil of Cedar-wood consists of *Cedrene*, $C_{32}H_{24}$ (liquid), and the solid $C_{32}H_{26}O_2$;

Oil of Winter-green consists of *Salicylate* of Oxide of Methyl, $C_{14}H_4O_6$,HO,MeO;

Oil of Valerian, consists of *Valerol*, $C_{12}H_{10}O_2$, *Borneene* (a camphor), and Valeric acid.

Properties.—It will be observed that these oils are generally composed of a fluid portion, which is a hydrocarbon, and a solid, containing, in addition to carbon and hydrogen, oxygen. The latter, by oxidization, may sometimes be changed to acids. These solid essential oils, or stearoptens, are sometimes included under the general head of

CAMPHORS,

From their close resemblance to the two crystalline oxidized essences, originally known under this name, viz.,

Japan Camphor, $C_{20}H_{16}O_2$, and Borneo Camphor, $C_{20}H_{18}O_2$

Preparation.—The former is obtained by distilling with water the roots and leaves of the *Laurus camphora*, a tree

found chiefly in Japan; the latter from the *Dryabalanops camphora*, a native of Borneo.

Properties.—They dissolve sparingly in water, abundantly in alcohol and ether. When enclosed in a glass vessel they vaporize, and are afterwards condensed in small crystals upon the side of the vessel which is exposed to the light. In contact with Nitric acid the former is oxidized to *Camphoric acid*, $C_{20}H_{14}O_6,2HO$; the latter to Japan Camphor. By action of oxygen on volatile oils still another class of allied substances is formed, the

RESINS AND BALSAMS.

The type of this class is common *rosin*, or *colophony*, which is formed by the abstraction of 1 equivalent of hydrogen in Oil of Turpentine by the oxygen of the air to form water; thus, Oil of Turpentine, $C_{20}H_{16}+O=C_{20}H_{15}+HO$; and further oxidation of the body thus formed, $C_{20}H_{15}$, to *Pinic* and *Sylvic* acids, both of which have the formula $C_{20}H_{15}O_2$. A mixture of these two acids constitutes rosin.

Lac, or **Gum Lac,** as it is frequently termed, exudes from the punctures made in the *Ficus* tree by insects. It is soluble in alcohol, oil of turpentine, and hot solution of borax. It is of very complex composition, consisting of no less than five different resins. Largely used in varnishes, in hat making, and forms the chief part of *sealing-wax*. Its most important varieties are *Stick-lac*, *Seed-lac*, and *Shellac*.

Mastic, Dammar-resin, Sandarac, and **Copal,** are resinous products from trees growing in hot climates. They are largely employed in varnishes.

Amber is a resin which has exuded, in some past geological era, from trees now extinct, and which is cast up on the shores of the Baltic and the coast of New Jersey

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in masses of a few ounces in weight. It is fashioned on the lathe into ornaments, and is made into varnish.

Caoutchouc, or **Gum-elastic**, **India-rubber**, and **Gutta Percha**—are the dried juices of certain tropical plants. They are insoluble in water and alcohol; sparingly soluble in ether and the essential oils. Largely soluble in chloroform. In oil of turpentine, especially when holding sulphur in solution, Caoutchouc dissolves to a viscid, sticky substance. By heating with sulphur the elasticity of Caoutchouc is increased, and it is rendered less liable to be affected by differences of temperature. The new substance thus formed, and which is known as *Vulcanized India-rubber*, is employed in the manufacture of combs, brushes, knife-handles, etc.

The Balsams, such as *Venice Turpentine, Canada Balsam*, etc., are natural solutions of resins in essential oils. Some, as *Peru* and *Tolu Balsams*, and *Gum Benzoin*, contain in addition benzoic or cinnamic acid.

(c) Essential Oils Containing Sulphur.

The two most important of this class are:—

Oil of Black Mustard, $C_8H_5NS_2$, and

Oil of Garlic, C_6H_5S.

Preparation.—The former does not pre-exist in the seed, but is formed in the process of distillation by the joint action of water and *Myronic acid* upon the pulpy matter of the bruised seed, after the fixed oil which it contains has been expressed. (See Oil of Bitter Almonds, p. 246.)

Composition.—Oil of Mustard is supposed to be a compound of Sulphocyanogen, C_2NS_2 (p. 273), with a hydrocarbon, C_6H_5, known as *allyl*, forming Sulphocyanide of Allyl; thus, $C_8H_5NS_2 = C_6H_5C_2NS_2$.

In like manner garlic oil is regarded as a Sulphide of Allyl, C_6H_5S.

VI. CYANOGEN AND ITS COMPOUNDS.

In consequence of its close resemblance to the halogens this important radical has already been described, p. 164. Like the halogens it forms one acid compound with hydrogen, and many compounds with the metallic elements which have the properties of salts, viz.: —

Hydrocyanic or Prussic Acid, HC_2N or HCy. (Sym. of Cyanogen, Cy.)

Preparation. — Produced by decomposing Cyanide of Mercury with Sulphuretted Hydrogen, $HgC_2N + HS = HgS + HC_2N$.

Properties.—A thin, colorless liquid, boiling at 79° and freezing at 0°. It is very volatile, has a peachy odor, and is fearfully poisonous. Best antidote is ammonia. Its acid properties are very feeble. Rapidly decomposes, especially when exposed to light.

Salts of Hydrocyanic Acid. — The Cyanides of Potassium and Sodium may be obtained by burning Potassium or Sodium in Cyanogen gas. For commercial use, however, Cyanide of Potassium, KCy, is prepared by decomposition of Ferrocyanide of Potassium (p. 272).

Cyanide of Mercury, HgCy, may be obtained by decomposing Cyanide of Potassium with Red Oxide of Mercury, $KCy + HgO = KO + HgCy$. It is valuable as a source of Cyanogen.

The **Cyanides of Silver and Gold,** AgCy and $AuCy_3$, are largely employed in solution with Cyanide of Potassium as baths for silver and gold electro-plating.

Compounds of Cyanogen with Oxygen.

With oxygen Cyanogen forms three isomeric acids: —
Cyanic acid, C_2NO;
Fulminic acid, $C_4N_2O_2$; and

Cyanuric acid, $C_6N_3O_3$.

The first is monobasic, the second bibasic, the third tribasic. Thus in combination with silver we have

Cyanate of Silver, AgO,C_2NO;

Fulminate of Silver, $2AgO,C_4N_2O_2$;

Cyanurate of Silver, $3AgO,C_6N_3O_3$.

Cyanic acid, C_2NO, may be combined with Ammonia to form a crystalline *Cyanate of Ammonia*, NH_4O,C_2NO. By heating or by exposure to air a little Ammonia is evolved, and the crystals are found to have undergone a wonderful change, and become *urea*.

The compound of Fulminic acid with silver, $2AgO$, $C_4N_2O_2$, is a dangerously-explosive, crystalline solid.

Compound of Cyanogen with Iron.

Ferrocyanogen—C_6N_3Fe, (Sym. Cfy). This radical has never been isolated.

Preparation.—It may be obtained as a Ferrocyanide of Potassium, K_2,C_6N_3Fe, by digesting iron filings in a solution of Cyanide of Potassium; Oxygen is absorbed, and we have $3KCy+Fe+O=KO+K_2,C_6N_3Fe$. In larger quantities for commercial purposes, this salt is procured by heating the horns, hoofs, hides, or other parts of animals with Carbonate of Potassa and iron filings. It is repeatedly crystallized from solution until it forms large, transparent, lemon-yellow crystals, known in commerce as *Yellow Prussiate of Potash*, $K_2C_6N_3Fe+3HO$.

When Ferrocyanide of Potassium is added to solutions of metallic salts it forms oftentimes a beautifully colored precipitate, which is valuable as a test. The Potassium is simply replaced by the metal; thus, $K_2C_6N_3Fe + 2(CuO,NO_5)=2(KO,NO_5)+Cu_2C_6N_3Fe$.

Hydroferrocyanic Acid—H_2Cfy. Like Cyanogen, this radical also combines with Hydrogen to form an acid.

But Hydroferrocyanic acid is entirely different from its corresponding cyanogen compound, being very permanent, and strongly acid. It is formed by decomposing Ferrocyanide of Copper with Sulphuretted Hydrogen, $Cu_2C_6N_3Fe + 2HS = 2CuS + H_2C_6N_3Fe$.

Remarks. — It will be observed, that in combination with the metals and hydrogen, Ferrocyanogen is bibasic.

Ordinary Prussian Blue, Fe_4Cfy_3, is formed when Ferrocyanide of Potassium is added to a Sesquisalt of Iron: thus, $3K_2Cfy + 2(Fe_2O_3, 3NO_5) = 6(KO, NO_5) + Fe_4Cfy_3$. It is employed both in water colors, and in oil paintings, as an intense blue color, but it is not permanent. Dissolved in water by means of Oxalic acid, it forms *blue* ink.

Basic Prussian Blue, $Fe_4Cfy_3 + Fe_2O_3$, is formed by exposing the white precipitate, which is formed when a ferrocyanide is added to a solution of an iron protosalt, to the air.

Ferricyanogen—$C_{12}N_6Fe_2$. Sym. Cfdy.

Preparation. — A salt radical, isomeric with Ferrocyanogen, which may be obtained as a Ferricyanide, by passing chlorine into a solution of Ferrocyanide of Potassium.

Properties.—It combines with three equivalents of Potassium to form *Ferricyanide of Potassium,* or, as it is termed in commerce, *Red Prussiate of Potash,* K_3Cfdy, and with 3 equivalents of the other metals, and of hydrogen. It is therefore tribasic.

Remarks.—With a Sesquisalt of Iron, Ferricyanide of Potassium produces no precipitate; with a Protosalt, it forms *Turnbull's Blue,* Fe_3Cfdy.

A radical, termed *Cobaltcyanogen,* and others, having cobalt in place of iron, and similar in its properties and compounds to ferricyanogen, has been formed.

Sulphocyanogen—C_2NS_2. Sym. Csy.

Preparation.—A salt radical, which may be obtained

in combination with Potassium and Iron, by heating sulphur with yellow Prussiate of Potash; $K_2C_6N_3Fe + 6S = 2(KC_2NS_2) + FeC_2NS_2$.

Properties.—It forms an acid compound with hydrogen, *Hydrosulphocyanic acid*, HCsy, and unites with metals to form salts. Those which are soluble, give a characteristic blood-red color with Sesquisalts of Iron, but no precipitate. Exists in the saliva.

Remarks.—Sulphur may be replaced by Selenium, and *Selenocyanogen* and its compounds, analogous to Sulphocyanogen and the Sulphocyanides, be formed.

VII. ORGANIC COLORING PRINCIPLES.

All colors may be obtained from organic substances, but the prevailing tints are red, yellow, blue, and green, of very various tones and intensities. They are all derived from vegetables, with the exception of cochineal.

The *Art of Dyeing* consists in applying the pigment in such a way that it cannot be washed off. As a general rule, the coloring matter has not sufficient affinity for the fibre of the fabric to resist washing. Recourse must then be had to an intermediate body, having a strong attraction for both the fabric and the coloring matter, which may serve to fasten the two together. Such a body is termed a *mordant*, and the three principal mordants are *Alumina, Oxide of Tin*, and *Sesquioxide of Iron*. When an infusion of a dye-wood, like logwood, is mixed, for example, with alum and a little alkali, the acid of the alum combines with the alkali, and sets alumina free. The alumina then combines with the coloring matter, forming a precipitate, technically called a *lake*, which permanently attaches itself to the fabric. Alumina and

Oxide of Tin form bright, Sesquioxide of Iron, dull lakes. When the *mordant* is applied only to a portion of the fabric, by means of a pattern, all the coloring matter in the rest of the fabric can be washed out, and a figure corresponding to the pattern will be left firmly fastened to the stuff.

Coloring principles have, as a general rule, stronger affinities for animal substances, such as wool and silk, than those of vegetable origin, like cotton and flax. The most important organic coloring matters are:—

Indigo.
Litmus.
Madder: Alizarin and Purpurin.
Safflower: Carthamine.
Brazil-wood and Logwood: Hematoxylin.
Quercitron; Fustic-wood; Saffron; Turmeric.
Cochineal.
Chlorophyle.

Indigo—$C_{16}H_5NO_2$.

Preparation.—It is obtained by digesting the leaves of several species of the genus *Indigofera* for eight or ten days in water. A yellow substance is formed, which by oxidation changes to a deep blue, and constitutes commercial Indigo. By sublimation of the commercial, pure Indigo, sometimes termed *Indigotine*, may be obtained.

Properties.—A tasteless, inodorous body, insoluble in water, but slightly soluble in alcohol. It dissolves in strong Sulphuric acid, and forms Sulphindigotic or Sulphindylic acid, $C_{16}H_4NO,2SO_3,HO$. This solution is used as a chemical test, and in dyeing.

By deoxidizing agents, such as *Protosulphate of Iron* and *Protochloride of Tin*, the color of Indigo may be entirely removed, and white Indigo, $C_{16}H_6NO_2$, be formed. This unites with bases and forms with them soluble compounds, which are admirably adapted for dyeing purposes

By exposure these solutions become deep blue. It is on this principle that dyeing with Indigo is performed.

By boiling powdered Indigo with Hydrate of Potassa it is changed to Aniline, $C_{16}H_5NO_2 + 4(KO,HO) + 2HO = C_{12}H_7N + 4(KO,CO_2) + 4H$ (p. 247).

Litmus—*Archil*, *Turnsol* or *Cudbear*. These blue coloring matters are obtained from the *Rocella tinctoria* and other lichens by exposing them in a moistened condition to the action of Ammonia.

Properties.—The blue color of litmus is changed to red by acids, and restored by alkalies, and it may be used, therefore, to detect their presence. It is largely employed as a red dye. It is a compound of several principles, as *Picro-erythrin*, $C_{24}H_{16}O_4$; *Orcein*, $C_{14}H_8O_4$; *Rocellinin*, $C_{18}H_8O_7$; and different acids.

Madder—*Alizarin* and *Purpurin*.

This is the finest and most permanent of red dyes. It is obtained from the root of the *Rubia tinctoria*, which is extensively grown in southern France, the Levant, etc. Besides yellow coloring matters, it yields the beautiful *Madder purple*, or *Purpurin*, $C_{18}H_6O_6 + 2HO$, and *Madder red*, or *Alizarin*, $C_{20}H_6O_6 + 4HO$. The latter is the chief coloring principle of madder. It is feebly acid. By oxidization with Nitric acid both are changed to Oxalic and *Phthalic* acids, $C_{20}H_6O_6 + 2HO + 8O = 2(C_2O_3,HO) + C_{16}H_6O_8$.

By appropriate mordants Madder furnishes likewise brown and orange colors, and the exquisite crimson known as *Turkey red*.

Safflower affords a yellow and a red dye (*carthamin*).

Brazil-wood and **Logwood.**—The former yields a crystalline solid, termed *brezeline*, which gives with mordants a beautiful red; the latter, by digestion in water, affords crystals of Hematoxylin, $C_{16}H_7O_2$. Produces with iron

salts a permanent black, and with other mordants different shades of purple and red.

Red ink is usually made by boiling about two ounces of Brazil-wood in a pint of water for a quarter of an hour, and adding a little gum and alum.

Quercitron; Fustic-wood; Saffron; Turmeric. — Furnish yellow dyes. The color of Turmeric is changed to brown by alkalies, for which it may therefore be employed as a test.

Cochineal. — A brilliant red dye, obtained by steeping the dried bodies of a little insect, the *Coccus cacti*, in water or alcohol. It is precipitated by alumina and oxide of tin, as *carmine*.

Chlorophyle. — A waxy substance, of a green color, formed in those parts of plants which are exposed to light, and communicating to them their green tinge.

VIII. ALBUMINOUS BODIES.

The three most important are *Albumen*, *Fibrin*, and *Casein*. They all agree in yielding, as the first product of their decomposition by caustic alkali, *protein* (from *proteuo*, I am first); and some have supposed that the combination of protein with sulphur and phosphorus produced Albumen, Fibrin, and Casein. This is doubtful.

Protein—$C_{24}H_{17}N_3O_8$.

A white, inodorous solid, capable of combining with both acids and bases. It is precipitated from its acid compounds by tannic acid and alkalies.

The chemical formulæ of Albumen, Fibrin, and Casein have not been determined, but they contain, as far as can be learned with regard to bodies which, like these, are amorphous, in 100 parts: —

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	Albumen.	Fibrin.	Casein.
Carbon	53.5	52.7	53.83
Hydrogen	7.0	6.9	7.15
Nitrogen	15.5	15.4	15.65
Oxygen	22.0	23.5	} 23.37
Sulphur	1.6	1.2	
Phosphorus	0.4	0.3	

The above analyses show that they closely agree in composition, and they may indeed, under certain circumstances, be converted into each other.

Albumen.

Source.—It is found nearly pure in the white of eggs, from which it derives its name, in the serum of blood, and in vegetables.

Properties.—It exists in two states; as a liquid in the white of eggs, the humors of the eye, serum of the blood, etc., and as a solid in the brain and nerves of animals, and in the seeds of plants. In the former condition it is colorless, tasteless, inodorous, and soluble in alkaline solutions; in the latter a translucent, horny, amorphous body. Liquid Albumen is coagulable by heat, by nitric, sulphuric, hydrochloric and metaphosphoric acids, by metallic salts, by astringent bodies, like tannic acid and creosote, and by alcohol. Owing to its coagulation by corrosive sublimate, Albumen is useful as an antidote. Its coagulation by acids is due to its combination with them as a base; by metallic salts, to its union with the oxide of the metal as an acid.

Fibrin.— Like albumen it exists in two states; 1st, as the chief component of muscular fibre, whence its name, in the clot of blood, etc.; 2nd, as gluten, the adhesive, pasty mass obtained from cereal grains after the starch has been removed.

Properties. —When fresh it forms white, elastic filaments, which are tasteless, inodorous, and insoluble, ex-

cept in alkaline liquids. It coagulates spontaneously, and forms the clot in blood. The Fibrin obtained from venous blood, however, is not identical with that of arterial blood, and neither agree in composition with the Fibrin of the flesh.

Casein.

Source.—Is found in the curd of milk (*caseum*, whence its name), in the blood, and in peas, beans, and similar plants—vegetable Casein, or *legumine.*

Properties. — It is soluble in alkaline solutions. Its solution in milk is due to the alkali present, and if the latter be removed by an acid, like lactic acid, the Casein coagulates and forms *curd.* The same effect is produced by the dried stomach of a calf, *rennet.*

There are many other proximate organic principles containing nitrogen, such as *Albuminose, Pancreatin, Mucosin, Crystallin, Musculin, Ostein, Keratin, Synovin, Spermatin,* etc, but we will consider only *Gelatin* and *Kreatin.*

Gelatin.

Source. — By the action of hot water on animal membranes, skin, tendons, and bones, they are made to dissolve and to furnish solutions, which on cooling deposit a yielding, tremulous mass, called *Gelatin.* It is familiar as calves'-foot jelly, and in the dry state as glue and isinglass, or the dried swimming-bladder of the sturgeon.

Properties. — As already mentioned (p. 251), the process of tanning depends upon the formation of an insoluble compound of the Gelatin contained in the hides with tannic acids.

The Gelatin obtained from cartilages differs from the above, and is termed *chondrin.* While Gelatin proper affords no precipitate with alum and acetate of lead, chondrin does.

Kreatin—$C_8H_9N_3O_4,2HO.$ It is a colorless and beauti-

fully crystalline body, which may be obtained from the juices of the flesh.

Of the animal fluids we shall consider,

1. Blood.

Description.—When freshly drawn it appears to be a homogeneous, red fluid, of slightly saline taste, peculiar odor, and somewhat unctuous touch. Under the microscope, however, it is found to consist of a nearly colorless

Fig. 162.   Fig. 163.

liquid, *serum of the blood,* or *liquor sanguinis,* and multitudes of little red discs, the *red corpuscles,* and colorless globules, *white corpuscles.* Fig. 162 shows the corpuscles in the blood of a frog, and Fig. 163 as they appear in human blood.

On standing, the fibrin and corpuscles form a *coagulum* or *clot,* and leave the thin, yellowish fluid, termed *serum,* in a pure state.

The analysis of blood gives:—

Water	784.
Red Corpuscles	131.
Albumen	70.
Salts	6.03
Fatty substances and Extractive matters	6.77
Fibrin	2.2
	1000.00

The salts found in the blood are chloride of sodium and potassium; carbonates, phosphates, and sulphates of potassa and soda; carbonates of lime and magnesia; phosphates of lime, magnesia, and iron.

The extractive matters are *kreatin,* fatty bodies like *seroline,* and *cholesterin* which is likewise found in bile, oleic, margaric, and other acids.

A most delicate test for blood is furnished by certain dark lines of absorption, seen with the spectroscope, p. 56. (See London Quarterly Journal of Science, April, 1865, p. 198.)

2. **Bile.** — It is a yellow or green fluid, of unpleasant smell and extremely bitter taste. It consists of various salts, fats, mucus, and other substances found in other solutions, along with a peculiar fat, termed *cholesterin,* and a resinous body, *bilin.*

3. **Saliva.**—It is characterized by the presence of a peculiar principle, termed *ptyaline,* and also contains sulphocyanogen.

4. **Gastric Juice.** — In addition to muriatic and lactic acids, and various salts, the gastric juice contains *pepsin,* to which its digestive power is chiefly due.

5. **Milk** consists of a watery fluid, in which are suspended globules of butter, surrounded by albuminous envelopes, and holding in solution various salts and milk-sugar. By churning these envelopes are broken, and the butter collects into a mass.

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APPENDIX.

EXTENSION has three dimensions, length, breadth, and thickness. These may be considered separately, in pairs, or all together.

Extension in length is measured and expressed by certain arbitrary scales and units, shown in the following tables, where the relation of various units is also given.

Measure of Length used in the United States.

Miles.	Furlongs.	Chains.	Rods.	Yards.	Feet.	Inches.
1.	8.	80.	320.	1760.	5280.	63360
.125	1.	10.	40.	220.	660.	7920
.0125	.1	1.	4.	22.	66.	792
.003125	.025	.25	1.	5.5	16.5	198
.00056818	.0045454	.045454	.181818	1.	3.	36
.00018039	.00151515	.0151515	.060606	.33333	1.	12
.000015783	.000126262	.001262626	.00505050	.027777	.083333	1

Length and breadth multiplied, or taken together, give surface. Thus, a rectangular area measuring one yard on each of its sides we call a square yard, and by the same term denote any area of equal extent, whatever its shape.

Measure of Surface used in the United States.

Square Miles.	Acres.	Square Chains.	Square Rods.	Square Yards.	Square Feet.	Square Inches.
1.	640.	6400.	102400.	3097600.	27878400.	4014489600.
.0015625	1.	10.	160.	4840.	43560.	6272640.
.0001562	.1	1.	16.	484.	4356.	627264.
.00009764	.00625	.0625	1.	30.25	272.25	39204.
.00000333	.0012066	.012066	.0830	1.	9.	1296.
.000000358	.0000206	.00002296	.00367	.111111	1.	144.
.0000000025	.000000143	.00001143	.00003568	.0007716	.00006944	1.

Length, breadth, and thickness united, that is multiplied together, give cubic capacity, or material bulk. This is the only sort of extension which can exist in matter. Length and surface are convenient for expression, but cannot exist alone.

Measures of Capacity.

Cubic Yard.	Barrel.	Bushel.	Cubic Feet.	Pecks.	Gallons.	Cubic Inch.
1.	5.6103	25.2457	27.	100.987	201.974	46656.
.1782	1.	4.5	4.8125	18.	36.	8316.
.03961	.2222	1.	1.3458	4.	7.47619	2150.42
.0870387	.2078	.804	1.	3.78009	7.48052	1728.
.09902	.05555	.25	.96788	1.	.5	462.
.004961	.02777	.125	.13809	.5	1.	231.
.00002148	.0001202	.000465	.0005787	.0021645	.0043290	1.

Dry Measure.

4 gills	=	1 pint.
2 pints	=	1 quart.
8 quarts	=	1 peck.
4 pecks	=	1 bushel.

Cubic Measure.

1728 cubic inches = 1 cub. foot.
27 " feet = 1 " yard.
128 " " = 1 cord.
40 feet round, 50 feet square,
'timber = 1 ton.

Liquid Measure.

4 gills	= 1 pint.
2 pints	= 1 quart.
4 quarts	= 1 gallon.
16 gallons	= 1 half barrel.
31½ "	= 1 barrel.
42 "	= 1 tierce.
63 "	= 1 hogshead.
84 "	= 1 puncheon.
2 hogsheads	= 1 pipe or butt.
2 pipes	= 1 tun.

Table for Comparison of French and English Measures for Length.

Metre	1 =	2 =	3 =	4 =	5 =	6 =	7 =	8 =	9 =
Yards	1.093	2.187	3.280	4.374	5.468	6.561	7.655	8.749	9.842
Feet	3.280	6.561	9.842	13.123	16.405	19.685	22.966	26.247	29.528
Inches	39.390	78.741	118.112	157.483	196.853	236.224	275.595	314.966	354.337
Decimetre	1 =	2 =	3 =	4 =	5 =	6 =	7 =	8 =	9 =
Feet	0.328	0.656	0.984	1.312	1.640	1.968	2.296	2.624	2.952
Inches	3.937	7.874	17.811	15.748	19.685	23.622	27.559	31.496	35.433
Centimetre	1 =	2 =	3 =	4 =	5 =	6 =	7 =	8 =	9 =
Inches	0.393	0.787	1.118	1.574	1.968	2.362	2.755	3.149	3.543
Millimetre	1 =	2 =	3 =	4 =	5 =	6 =	7 =	8 =	9 =
Inches	0.039	0.078	0.118	0.157	0.196	0.236	0.275	0.314	0.354

Example of method employed with this Table to reduce French to English measure.

Required to reduce 4672 Metres to Feet.

4000 Metres	=	13123.	feet.
600 "	=	1968.5	"
70 "	=	229.66	"
2 "	=	6.56	"
4672 "	=	15327.72	"

Select from the table the number corresponding to each digit in the given number, assigning the proper position to the decimal point; then add all these quantities; their

sum will be the required equivalent to the quantity stated.

Table for Comparison of French and English Measures of Surface.

Hectare.	Decare.	Are.	Sq. Metre.	Square Yards.	Square Feet.
1	10	100	10000	11966.4	107698.
	1	10	1000	1196.64	10769.8
		1	100	119.66	1076.98
			1	1.19	10.76, etc.

Table for Comparison of French and English Measures of Capacity.

	Kilolitre.	Hectolitre.	Decalitre.	Litre.	Decilitre.	Centilitre.
	1.	10.	100.	1000.	10000.	100000.
		1.	10.	100.	1000.	10000.
			1.	10.	100.	1000.
				1.	10.	100.
					1.	10.
Gallons........	220.	22.	2.2	.22	.022	1.
Quarts	881.2	88.12	8.81	.881	.0881	.00881
Pints...........	1762.4	176.24	17.62	1.762	.1762	.01762
Cubic Inches	61074.	6107.4	610.74	61.074	6.1074	.61074

Stere = 1 cubic metre = 35.31658 cubic feet.

Table, showing the Behavior of Solutions of Metals with Hydrosulphuric Acid and Hydrosulphate of Ammonia, employed successively. (Dr. Will.) The rarer metals are printed in italic.

Elements precipitated from their acid solution by HYDROSULPHURIC ACID, as sulphides.		Bodies precipitated by HYDROSULPHATE OF AMMONIA.		
Soluble in Hydrosulphate of Ammonia, and reprecipitated by Hydrochloric Acid.	Insoluble in Hydrosulphate of Ammonia.	As Sulphides.	As Oxides.	As Salts.
Anti-mony } Orange.	Mercury ⎫ Black or brownish-black.	Nickel ⎫ Black. Cobalt ⎭	Alumina ⎫ Soluble in potash. Glucina Chromium ⎭	Baryta, Strontia, Lime, in combination with phosphoric, boracic, oxalic, and some other acids.
Arsenic ⎫ Yellow. Tin ⎭	Silver Lead	Manga-⎫ Flesh-nese ⎭ color'd.		
Gold ⎫ Black. Platinum Iridium ⎭	Bismuth Copper Cadmium, Yellow	Iron, Black. Zinc, White.	Thorina ⎫ Insoluble in potash. Yttria Cerium Zirconia Titanium Tantalium ⎭	Magnesia in combination with phosphoric, acid.
Molyb-⎫ Brown. denum ⎭	Palladium ⎫ Brownish-black. Rhodium Osmium ⎭	Ura- ⎫ Brown-nium ⎭ ish-black.		

Weight. — Three scales are in use. The Troy and Apothecaries' are commensurate, but the Avoirdupois has a different standard.*

Measures of Weight used in the United States.

Avoirdupois.

Tons.	Cwts.	Pounds.	Ounces.	Drachms.
1.	20.	2240.	35840.	573440
.05	1.	112.	1792.	28672
.00044642	.0089285	1.	16.	256
.00002790	.000558	.0625	1.	16
.00000174	.0000348	.0016	.0625	1

The short ton contains 2000 lbs.

Troy.

Pounds.	Ounces.	Dwts.	Grains.	Pound Avoir.
1.	12.	240.	5760	.822861
.083333	1.	20.	480	.068571
.004166	.050000	1.	24	.0034285
.0001736	.0020833	.041666	1	.00020571
1.215275	14.58333	219.666	7000	1.

Troy weight only is used in philosophical experiments.

Apothecaries'.

Pound.	Ounces.	Drachms.	Scruples.	Grains.
1.	12.	96.	288.	5760
.08333	1.	8.	24.	480
.0104166	.125	1.	3.	60
.0034722	.041666	.3333	1.	20
.00017361	.020833	.1666	.05	1

* The Troy or Apothecaries' pound is to the Avoirdupois pound as 144 is to 175, but the ounces are as 480 grains to 437½ grains Troy or Apothecaries'. So also the Apothecaries' drachm = 60 and the Avoirdupois drachm = 27½½ grains Troy or Apothecaries'.

Table for Comparison of French and English Measures of Weight.

	1 =	2 =	3 =	4 =	5 =	6 =	7 =	8 =	9 =
Kilogramme............									
Pound Avoirdupois...	2.204	4.409	6.614	8.819	11.024	13.229	15.434	17.638	19.843
" Troy............	2.679	5.359	8.038	10.718	13.397	16.077	18.756	21.436	24.116
Gramme................									
Grains.................	15.442	30.884	46.327	61.769	77.212	92.655	108.096	123.539	138.981
Decigramme..........									
Grains.................	1.5442	3.0884	4.6327	6.1769	7.7212	9.2655	10.8096	12.3539	13.8981
Centigramme..........									
Grains.................	.1544	.3088	.4632	.6177	.7721	.9265	1.0809	1.2353	1.3898
Milligramme..........									
Grains.................	.0154	.0308	.0463	.0617	.0772	.0926	.1081	.1235	.1390

For use of table, see example on

Table of Densities, or Specific Gravities.

Solids and Liquids are compared with Water at 60°
Fahr. as 1; Gases with Air at 60° and Barometer at 30
inches as 1. Air is to water, under these conditions, as
1 to 815.

Alabaster......................	1.870	Gold, hammered...........	19.36
Alcohol, absolute............	.793	" pure and cast.......	19.25
" 95 per cent........	.808	Gum Arabic and Honey..	1.45
" 85 per cent........	.835	Hen's Egg....................	1.05
" and Water, 1:1..	.930	Hydrogen Gas	.069
Alum	1.72	Ice	.93
Amber...........................	1.08	Iron, cast.....................	7.20
Antimony, cast	6.71	Iron, malleable.............	7.79
Ash..............................	.84	Isinglass	1.11
Asphaltum.....................	1.40	Ivory	1.91
Atmospheric Air	1.00	Jasper	2.70
Beech...........................	.85	Jet	1.24
Bismuth, cast.................	9.82	Lead, cast.....................	11.35
Brass, cast.....................	8.40	Lignum Vitæ................	1.33
" wire.....................	8.54	Lime, Carbonate of........	2.71
Camphor	.099	Linseed Oil......	.094
Carbonic Acid Gas..........	1.52	Mahogany.....................	1.06
Chlorine........................	2.47	Mercury.......................	13.59
Coal, from ....1.24 to	1.30	Muriatic Acid...............	1.20
Cobalt and Nickel, cast....	7.81	Naphtha.......................	.84
Copper, cast..................	8.85	Nitre...........................	2.00
" wire..................	8,89	Nitric Acid, concentrated	1.45
Cork	.24	Oak, dry, heart.............	1.17
Diamond	3.50	Olive Oil......................	.91
Ebony	1.33	Oxygen Gas..................	1.10
Fir	.65	Parian Marble..............	2.34
Flint............................	2.59	Phosphorus..................	1.77
Fluor Spar.....................	3.19	Platinum, cast	19.05
Garnet, Bohemian ..3.69 to	3.80	" hammered......	23.00
Glass, Flint, French........	3.20	" drawn into wire	21.04
" " English	3.37	Plumbago	2.55
" " Frauenhofer	3.77	Poplar..........................	.38
" Bottle.	2.60	Rock Crystal.................	2.65
" Plate.....................	2.37	Salt, common	2.18

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Silver, hammered............	10.51	Sulphuric Ether...............	.71
" pure and cast.......	10.47	Sulphuric Acid, concentra-	
Steel, hammered	7.81	ted	1.84
" soft	7.80	Tallow	.94
Sugar, white..................	1.61	Tin, cast	7.30
Sulphate of Baryta.........	4.43	Water, fresh.....................	1.00
" Lime............	2.32	Water, Sea......................	1.02
" Soda............	2.20	Wax, White.....................	.97
Sulphur, native	2.08	Zinc, cast........................	7.20

Table of Tenacities, or Breaking Weights.

Selected from Journal of Franklin Institute, Vol. 40, p. 340.

Power required to tear asunder one Sq. Inch, in Avoirdupois Pounds.

Copper, wrought.........	34,000	Ash.................12,000 to	16,000
" cast...............	24,250	Beech	11,500
" wire	61,200	Box..............................	20,000
Gold, cast	20,000	Cedar...........................	11,400
Iron, cast, Low Moor ...	14,067	Chestnut, Sweet............	10,500
" Mean of American	31,829	Locust	20,500
" wire..................	103,000	Mahogany.....................	21,000
" bar, Swedish	72,000	" Spanish.........	12,000
" " English	56,000	Oak, white, American....	11,500
" boiler plate.........	51,000	" " English	10,000
Lead, cast..................	1,800	Pine, white...................	11,800
" milled...............	3,320	Poplar	7,000
" wire	2,580	Teak, Java	14,000
Platinum, wire............	2,580	" African..............	17,000
Silver, cast	40,000	Walnut	7,800
Steel, cast, maximum ...	142,000	Willow	13,000
" spring...............	72,500	Brick.......................290 to	750
" plates, lengthwise	96,300	Chalk............................	118
" " crosswise.	73,700	Cement, Portland	400
" razor..................	150,000	Glass, plate...................	9,400
Tin, cast.....................	5,000	" crown................	6,000
Zinc, cast...................	3,500	Ivory	16,000
" sheet..................	16,000	Rope, Manilla................	3,200
Brass	42.000	" hemp..................	6,400
" yellow	18,000	" wire	37,000
Bronze ....17,698 to	56,788	Mortar	52
Gun-metal (Cu8:St1).....	30,000	Sandstone.....................	200

Table for converting Degrees of Centigrade into Degrees of Fahrenheit.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
100°	= −148.0°	−54°	= −65.2°	−8°	= +17.6°
99	146.2	53	63.4	7	19.4
98	144.4	52	61.6	6	21.2
97	142.6	51	59.8	5	23.0
96	140.8	50	58.0	4	24.8
95	139.0	49	56.2	3	26.6
94	137.2	48	54.4	2	28.4
93	135.4	47	52.6	−1	= 30.2
92	133.6	46	50.8	0	32.0
91	131.8	45	49.0	+1	= 33.8
90	130.0	44	47.2	2	35.6
89	128.2	43	45.4	3	37.4
88	126.4	42	43.6	4	39.2
87	124.6	41	41.8	5	41.0
86	122.8	40	40.0	6	42.8
85	121.0	39	38.2	7	44.6
84	119.2	38	36.4	8	46.4
83	117.4	37	34.6	9	48.2
82	115.6	36	32.8	10	50.0
81	113.8	35	31.0	11	51.8
80	112.0	34	29.2	12	53.6
79	110.2	33	27.4	13	55.4
78	108.4	32	25.6	14	57.2
77	106.6	31	23.8	15	59.0
76	104.8	30	22.0	16	60.8
75	103.0	29	20.2	17	62.6
74	101.2	28	18.4	18	64.4
73	99.4	27	16.6	19	66.2
72	97.6	26	14.8	20	68.0
71	95.8	25	13.0	21	69.8
70	94.0	24	11.2	22	71.6
69	92.2	23	9.4	23	73.4
68	90.4	22	7.6	24	75.2
67	88.6	21	5.8	25	77.0
66	86.8	20	4.0	26	78.8
65	85.0	19	2.2	27	80.6
64	83.2	18	= −0.4	28	82.4
63	81.4	17	= +1.4	29	84.2
62	79.6	16	3.2	30	86.0
61	77.8	15	5.0	31	87.8
60	76.0	14	6.8	32	89.6
59	74.2	13	8.6	33	91.4
58	72.4	12	10.4	34	93.2
57	70.6	11	12.2	35	95.0
56	68.8	10	14.0	36	96.8
55	67.0	9	15.8	37	98.6

Conversion of Centigrade into Fahrenheit—*continued.*

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
+38°	= +100.4°	+86°	= +186.8°	+134°	= +273.2°
39	102.1	87	188.6	135	275.0
40	104.0	88	190.4	136	276.8
41	105.8	89	192.2	137	278.6
42	107.6	90	194.0	138	280.4
43	109.4	91	195.8	139	282.2
44	111.2	92	197.6	140	284.0
45	113.0	93	199.4	141	285.8
46	114.8	94	201.2	142	287.6
47	116.6	95	203.0	143	289.4
48	118.4	96	204.8	144	291.2
49	120.2	97	206.6	145	293.0
50	122.0	98	208.4	146	294.8
51	123.8	99	210.2	147	296.6
52	125.6	100	212.0	148	298.4
53	127.4	101	213.8	149	300.2
54	129.2	102	215 6	150	302.0
55	131.0	103	217.4	151	303.8
56	132.8	104	219.2	152	305.6
57	134.6	105	221.0	153	307.4
58	136.4	106	222.8	154	309.2
59	138.2	107	224.6	155	311.0
60	140.0	108	226.4	156	312.8
61	141.8	109	228.2	157	314.6
62	143.6	110	230.0	158	316.4
63	145.4	111	231.8	159	318.2
64	147.2	112	233.6	160	320.0
65	149.0	113	235.4	161	321.8
66	150.8	114	237.2	162	323.6
67	152.6	115	239 0	163	325.4
68	154.4	116	240.8	164	327.2
69	156.2	117	242 6	165	329.0
70	158.0	118	244 4	166	330.8
71	159.8	119	246.2	167	332.6
72	161.6	120	248.0	168	334.4
73	163.4	121	249.8	169	336.2
74	165.2	122	251.6	170	338.0
75	167.0	123	253.4	171	339.8
76	168.8	124	255.2	172	341.6
77	170.6	125	257.0	173	343.4
78	172.4	126	258.8	174	345.2
79	174.2	127	260.6	175	347.0
80	176.0	128	262.4	176	348.8
81	177.8	129	264.2	177	350.6
82	179.6	130	266.0	178	352.4
83	181.4	131	267.8	179	354.2
84	183.2	132	269.6	180	356.0
85	185.0	133	271.4	181	357.8

Conversion of Centigrade into Fahrenheit.—*Continued.*

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
+182°	= +359.6°	+230°	= +446.0°	+278°	= +532.4°
183	361.4	231	447.8	279	534 2
184	363.2	232	449.6	280	536.0
185	365.0	233	451.4	281	537.8
186	366.8	234	453.2	282	539.6
187	368.6	235	455.0	283	541.4
188	370.4	236	456.8	284	543.2
189	372.2	237	458.6	285	545.0
190	374.0	238	460.4	286	546.8
191	375.8	239	462.2	287	548.6
192	377.6	240	464.0	288	550.4
193	379.4	241	465.8	289	552.2
194	381.2	242	467.6	290	554.0
195	383.0	243	469.4	291	555.8
196	384.8	244	471.2	292	557.6
197	386.6	245	473.0	293	559.4
198	388.4	246	474.8	294	561.2
199	390.2	247	476.6	295	563.0
200	392.0	248	478.4	296	564.8
201	393.8	249	480.2	297	566.6
202	395.6	250	482.0	298	568.4
203	397.4	251	483.8	299	570.2
204	399.2	252	485.6	300	572.0
205	401.0	253	487.4	301	573.8
206	402.8	254	489.2	302	575.6
207	404.6	255	491.0	303	577.4
208	406.4	256	492.8	304	579.2
209	408.2	257	494.6	305	581.0
210	410.0	258	496.4	306	582.8
211	411.8	259	498.2	307	584.6
212	413.6	260	500.0	308	586.4
213	415.4	261	501.8	309	588.2
214	417.2	262	503.6	310	590.0
215	419.0	263	505.4	311	591.8
216	420.8	264	507.2	312	593.6
217	422.6	265	509.0	313	595.4
218	424.4	266	510.8	314	597.2
219	426.2	267	512.6	315	599.0
220	428.0	268	514.4	316	600.8
221	429.8	269	516.2	317	602.6
222	431.6	270	518.0	318	604.4
223	433.4	271	519.8	319	606.2
224	435.2	272	521.6	320	608.0
225	437.0	273	523.4	321	609.8
226	438.8	274	525.2	322	611 6
227	440.6	275	527.0	323	613.4
228	442.4	276	528.8	324	615.2
229	444.2	277	530.6	325	617.0

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Conversion of Centigrade into Fahrenheit.—*Concluded.*

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
+326°	= +618.8°	+334°	= +633.2°	+342°	= +647.6°
327	620.6	335	635.0	343	649.4
828	622.4	836	636.8	344	651.2
329	624.2	337	338.6	345	653.0
830	626.0	338	640.4	346	654.8
831	627.8	339	642.2	347	656.6
332	629.6	340	644.0	348	658.4
833	631.4	341	645.8	349	660.2

Referred to on page 51.

To prepare a double-image prism of Iceland spar, we take a natural crystal of that substance, and using the natural face, B Y, Fig. 40; for one surface cut a pointed wedge from it so that the apex of said wedge shall be in the obtuse angle, Y, and the new face make with the natural one an angle of 8° to 10°. We then prepare a small prism of glass, having a little less angle, to correct the color dispersion of the spar prism, and cement these together with Canada balsam as usual.

Iceland spar may be cut first with a fine saw, then trimmed down with a file, "2nd cut, bastard," then ground with the *greatest care* with emery of *increasing fineness*, and, lastly, polished with a little crocus or rouge on leather. The best specimens of this work which I have ever seen, among hundreds by French and English makers, are prepared by J. Zentmeyer, Optician, of Philadelphia, who, I believe, is also the first successfully to work that difficult material in this country.

H. M.

LAWS OF CHEMICAL COMBINATION.

LAW I.

The same substance is always composed of the same elements in the same proportions. Thus, water, whether found in the blood of animals, the sap of plants, in minerals or chemical salts, in springs, rivers, the ocean or the clouds, consists always of Oxygen and Hydrogen combined, in the proportion of 8 parts by weight of the first to one of the second.

LAW II.

Each element has a certain proportion or number of parts by weight, in which it combines with others. This proportion is called its EQUIVALENT, or ATOMIC WEIGHT (being supposed to represent the relative weight of its final particle or atom). In these equivalent proportions (or in simple multiples of the same), elements will combine together, and in no other ratio. Thus, the equivalent of Nitrogen is 14, and that of Oxygen is 8; if, then, we bring together the bodies in this proportion they will combine, leaving no residue; but if we have 9 parts of Oxygen, then one part of this would

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be left out, and would not enter into combination with the Nitrogen. We may, however, have a double equivalent of Oxygen, i. e. 16 parts, combining with the 14 of Nitrogen; or a triple, 24 parts, or a quadruple, etc. Each of these compounds would then, however, be quite a different substance from the others. ·

LAW III.

The equivalent of a compound is equal to the sum of the equivalents of its constituents. Thus, the equivalent of water made of Oxygen 8, and Hydrogen 1, is 9. That of Nitric Acid, made of Nitrogen 14, and 5 times that of Oxygen (8), or 40, is 54 (NO_5. Eq. 54.)

LAW IV.

Like *classes* of bodies combine, with each other — Element with element, Binary with binary, Ternary with ternary. Thus, Zinc can combine with Oxygen, or some other element, but not with Sulphuric Acid (SO_3), or other binary compound; but Oxide of Zinc (ZnO), itself a binary, can combine with the binary Sulphuric Acid.

LAW V.

(a) When elements unite, the electro-positive by preference combine with the electro-negative. (b) When binaries unite, the electro-negative element in each must be the same. (c) When ternaries unite, the electro-negative binary must be the same, i. e. they must have the same acid.

Examples. — (a) Iron, which is positive, will unite more readily with Sulphur or Carbon, which are negative, than with Hydrogen, which is positive. (b) Again, in Oxide of Iron (FeO) the Oxygen is the negative ele-

ment; so also it is in Sulphuric Acid (SO_3); these may then combine; not so, however, Oxide of Iron and Hydrocloric Acid (HCl), where Oxygen is the negative element in one, and Chlorine in the other. (c) Lastly. Sulphate of Potash (KO,SO_3) may unite with Sulphate of Copper (CuO,SO_3), having the same acid, but not with Nitrate of Copper (CuO,NO_5), which has Nitric Acid for its negative binary.

It is found with regard to gases, that not only is their combining *weight* fixed, as we have already shown, but that they have a like relative *combining volume*. Thus, Oxygen and Hydrogen unite in the proportion of one volume of the first to two of the second. Hydrogen and Chlorine in equal volumes, and so with others.' Various attempts have been made to carry out this observation to solid and liquid bodies by finding or assuming their vapor volumes, and many elaborate deductions have been made from these data; but the subject is far too complicated to be discussed in such a work as the present.

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